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CHRONOLOGY OF DENNING BY BLACK BEARS IN THE CATSKILL REGION OF NEW YORK[1]

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ABSTRACT

Data on the use of dens were collected, with the aid of radio telemetry, from 62 black bears in the Catskill region of New York during the years 1975 to 1979. Den entry and emergence dates varied according to the sex and reproductive status of the bears. The median den-entry date for females with cubs (November 22) was somewhat earlier than those for pregnant females (November 24) and barren females (November 30). Collectively, females denned significantly earlier (November 24) than males (December 10). The median den-emergence dates also varied with sex and reproductive status. Males were the first to leave their dens (March 26), followed by females with yearlings (April 5) and barren females (April 8). Females with cubs stayed at their den sites significantly later (April 15) than males or females with yearlings.

Successful management of black bear (*Ursus americanus*) populations depends on formulating appropriate harvest strategies. Many variables must be considered in designing hunting seasons that will assure achievement of management objectives. Denning chronology is a variable of increasing concern to managers. Lindzey and Meslow (1976) reported variation between the sexes with respect to denning dates to be a significant factor. Willey (1978) recognized the potential management implications of early denning by female bears.

Differential den entry and/or emergence has been reported for black bears by several researchers. Erickson et al. (1964) reported that in Michigan adult males denned about 2 weeks after females and juveniles. Lindzey and Meslow (1976) reported adult males denning approximately 1 month after females in Washington. They also observed that yearlings differed from adults of both sexes, having an intermediate denning date. Jonkel and Cowan (1971) in Montana concluded that adults left their dens in the spring before subadults. Amstrup and Beechum (1976) in Idaho reported that females with young were the last to leave the den. In New

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project W-89-R-24.

York denning chronology has become an important consideration in designing hunting seasons for black bears inhabiting the Catskill region where hunting annually accounts for more than 90 per cent of all documented mortality (McCaffrey et al. 1976). Denning habits of the species in this region were studied from 1975 to 1979.

STUDY AREA

The bear range in the Catskills is the second largest of New York's three black bear ranges. It encompasses 3,330 square kilometers in the southeastern part of the State and is presently occupied by an estimated 400 bears. The geographic distribution of the bear harvest and other mortality, as well as the locations of contacts by radio telemetry, indicate the existence of two sub-populations in this region. The southern sub-population, which occupies about 1,080 square kilometers, is the smaller of the two and is contiguous with a bear population in northeastern Pennsylvania.

The northern sub-population, in which radio-telemetry studies were concentrated, consists of approximately 300 bears that presently occupy a range of about 2,250 square kilometers. The range is mountainous with elevations of from 300 to 1,281 meters (McCaffrey et al., 1976). It contains a major portion of the Catskill Forest Preserve (948 square kilometers) with extensive tracts of northern hardwoods and red spruce (*Picea rubens*) at the higher elevations (Stout, 1958). Vehicular access is restricted to the valleys; however, there is little bear range that is more than 2 miles from a road.

Soils are classed as poor to moderately productive, of glacial origin derived from sandstone and conglomerate (Howe, 1935). The highlands support little or no agriculture. Average July temperatures are between 18° and 21° C., and January averages range between $-7°$ and $-4°$ C. Annual precipitation is between 100 and 125 centimeters, about half of which occurs during the growing season. Annual snowfall averages from 100 to 150 centimeters (Smith, 1955). In the high peaks area, precipitation is typically much greater, the averages for one weather station in the center of the study area being 175 centimeters total precipitation and over 300 centimeters of snow (National Atmospheric and Oceanic Administration, 1975-1979).

The density of the resident human population is low and generally restricted to the lowlands and valleys. People are most numerous in summer and fall when visitors come to the region to hike, camp and vacation.

METHODS

Black bears were captured primarily with Aldrich cable foot snares, although a few were caught in culvert traps. Etorphine hydrochloride or

ketamine hydrochloride was used to immobilize the captured animals. Selected bears were fitted with radio-tracking transmitters, operating at 148 or 151 MHz. Radio locations for these individuals were desired weekly, but they were obtained only as weather and aircraft availability permitted.

The den entry date for an individual was defined as the midpoint between the last recorded movement in autumn and the first of a series of stationary signals indicating that it had denned. Den sites were visited early in the winter to document site characteristics, determine the reproductive status of the bears and replace radio collars if necessary. Reproductive status was determined by examining the bear itself or through analysis of audio tape recordings made within the dens using a portable cassette recorder and omnidirectional microphone. The date of den emergence was defined as the midpoint between the last winter denning date and the first spring movement recorded. Midpoints were selected to describe the denning and emergence of bears because they are probably least biased. There is no reason to suspect that actual dates tended to occur more on one side than the other of these midpoints. Furthermore, use of medians rather than means, to describe the activity of a class of bears, will be less influenced by individual variations among den entry or emergence dates. In some instances den emergence data were supplemented with the aid of a time-lapse camera (a Kodak Analyst modified as described by Slocum, 1977) positioned to permit photographing the den entrance and surrounding area. Weighted average dates for den entry and emergence were calculated with equal weight given to each class average.

A test for the equality of medians (Daniel, 1978) was employed to identify differences between years and classes. Average temperatures, snowfall and snow depths were evaluated by analysis of variance. The levels of significance were 0.05.

RESULTS

Sixty-two dennings, of 35 radio-equipped bears of known age, sex and reproductive status, were documented between 1975 and 1979. Male bears 3 years old or under were considered subadult, while barren females were considered subadult through 4 years. Over the 5-year study period, this sample consisted of 16 males (nine adult and seven subadult), 18 pregnant females, 15 barren females (eight adult and seven subadult) and 13 females denning with cubs. There were fewer males than females in the sample because adult males were captured much less frequently and mortality was higher among those captured. Bears in the sample varied from 1¾ to 16¾ years old (Table 1) as aged by cenentum annulation (Sauer et al., 1966).

Of the 62 instances of denning recorded, only 28 resulted in data for emergence. The causes for the difference were various. Two bears lost

TABLE 1. AGE, SEX AND REPRODUCTIVE STATUS OF BLACK BEARS ENTERING WINTER DENS ON THE STUDY AREA IN THE CATSKILL REGION, 1975-1979.

Age (years)	Males	Pregnant females	Barren females	Females with cubs
1	4	. .	2	. .
2	3	. .	1	. .
3	2	2	4	1
4	1	5	1	1
5	2	2	1	3
6	2	2	2	1
7	. .	. .	2	. .
8	. .	2	. .	. .
9	1	2	. .	2
10	. .	1	. .	1
11	. .	2	. .	2
12	. .	. .	. .	1
13	. .	. .	1	. .
14	. .	. .	1	1
15	. .	. .	. .	. .
16	1	. .	. .	. .
Total	16	18	15	13

TABLE 2. AGE, SEX AND REPRODUCTIVE STATUS OF BLACK BEARS EMERGING FROM WINTER DENS ON THE STUDY AREA IN THE CATSKILL REGION, 1976-1979.

Age (years)	Males	Females with cubs	Barren females	Females with yearlings
2	3	. .	2	. .
3	2	. .	1	. .
4	1	2	2	. .
5	1	3	1	. .
6	1	. .	1	1
7	. .	2	1	1
8	1	1	1	. .
9	1	2	. .	. .
10	. .	. .	. .	. .
11	. .	1	. .	1
12	. .	2	. .	. .
13	. .	. .	. .	. .
14	. .	. .	1	. .
15	. .	. .	. .	1
16	. .	. .	. .	. .
17	1	. .	. .	. .
Total	11	13	10	4

their collars, five radios failed, six dens were disturbed possibly inducing premature emergence and 11 bears were still in their 1979-80 dens as of this writing. The remaining sample consisted of 11 males (six adult and five subadult), 13 females with cubs of the year, 10 barren females (five adult and five subadult) and four females that emerged with yearlings. These bears ranged in age from 2 to 17 years (Table 2).

The recorded intervals between confirmed movement and confirmed denning varied between fall and spring, as well as between years and individuals. In addition to actual differences in behavior of the bears, variations in the data recorded resulted from irregular observation due to poor

flying conditions, other work assignments, inability to locate particular bears and aircraft availability. The average variation in the midpoint date for all bears in autumn was aproximately ±9 days, while the corresponding value for the spring was slightly less than ±5 days.

FEMALES WITH CUBS

Thirteen radio-equipped females accompanied by cubs, born the previous winter, were tracked to their winter dens. Although four years of records were available for this class, there were insufficient data for comparisons between years. The most data were available from 1979 when the median den entry date for females with cubs was December 10, but the median date for all females in the class over the 1976-1979 period was November 22 (Figure 1). A peak denning period cannot be readily identified from these data. Den entry dates appeared to be uniformly distributed about the median.

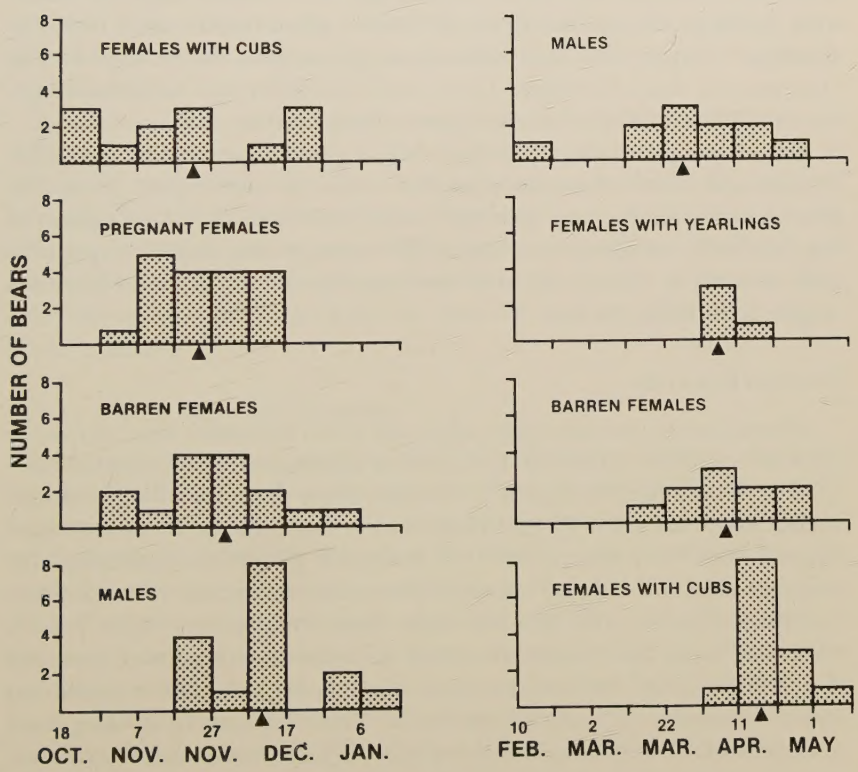

Figure 1. Frequency of den entry (left) and den emergence (right), by date, for different classes of bears in the Catskill region, 1975-1979. Arrow point represents median date.

Emergence data were available for only four females that left their dens with yearlings. The dates were between April 2 and April 12 (median = April 5, Figure 1). Small samples precluded comparisons between years.

PREGNANT FEMALES

Eighteen pregnant female bears were tracked to their winter dens. The earliest den entry for this class was October 31 (1979) and the latest was December 10 (1977). The median date for all pregnant females during the study was November 24 (Figure 1), while the median dates for 1976, 1977 and 1978 were, respectively, November 13, December 2 and November 30. Only one denning was documented in each of 1975 and 1979 (November 24 and October 31, respectively). A test for equality of medians detected no significant difference between years. Pregnant females were the least variable of all age classes; their entry dates were uniformly distributed from November 7 to December 17.

Emergence data were available for 13 bears in this class. All females with cubs stayed at their den sites through the end of March. Most data were available for the spring of 1979 when seven records were obtained (median = April 15). The median emergence date for all bears in this class was also April 15 (Figure 1). No statistical difference was detected between 1978 and 1979 in the emergence dates for this class.

Time-lapse photographs of three family groups suggest that the adult females and their cubs spent a portion of the two weeks prior to leaving their den sites loafing and "playing" in the immediate vicinity. It appeared that all family members returned to their dens in late afternoon, presumably remaining there until mid-morning the following day when they might again leave the den.

BARREN FEMALES

Fifteen barren females (eight adult and seven subadult) were tracked to their winter dens during the five years in which data were collected (median = November 30, Figure 1). Median entry dates for adults and subadults were November 29 and December 2, respectively. Den entry dates ranged from November 4 (1977) to December 27 (1978). Significant differences were not detected between the annual medians or class medians.

Barren females also entered their dens over a very wide period. However, there was a noticeable peak and the resemblance of a normal distribution about the median. Peak denning for this class occurred between November 17 and December 7. This variation may likely have resulted from the tendency of barren adult females to den earlier than barren subadult females. Although this difference was not significant, the small samples made it difficult to detect differences.

Emergence data were available for 10 bears (five adult and five subadult) in this class (median = April 6, Figure 1). Bears began to emerge as early as March 15 (1979) and continued to do so through April 28 (1979). Most data (four observations) were collected in the spring of 1978. Fewer emergences were documented in 1976, 1979 and 1977, i.e., 3, 2 and 1, respectively. Statistical differences were not detected between annual medians and class medians.

MALES

Data were recorded for 16 male bears (nine adult and seven subadult). Eight entered their dens during the second week of December (median = December 10, Figure 1), while for the others the den entry dates were scattered from November 19 to January 11. Most of the data were collected in 1977 (seven observations). In 1976 there were four observations, in 1978 there were three, and in 1975 and 1979 there was only one in each year. Tests for equality of medians for 1976 vs. 1977 and 1977 vs. 1978 did not reveal statistical differences, nor did a test of medians for adults vs. subadult males. Despite the extreme variability among the denning dates of males, there was a noticeable peak denning period narrowly surrounding the median.

Emergence data were available for 11 male bears (six adult and five subadult) as shown in Table 2. The median for all males was March 26 (Figure 1), while those for adults and subadults were March 25 and April 14, respectively. All bears stayed in their dens later in 1978 than in any other year. Despite this apparent difference, no significant difference was detected between the emergence dates for 1978 and those for any other year. Moreover, differences were not detected between other years or age-group medians.

ENTRY DATES BETWEEN CLASSES

Females with cubs, pregnant females and barren females exhibited statistically similar median den entry dates of November 22, 24 and 30, respectively. Pregnant females and barren females each denned significantly earlier than males, for which the median was December 10. The comparisons were, respectively, as follows: $Z = 2.44$, $P < 0.01$ and $Z = 2.15$, $P < 0.02$. Although females with cubs exhibited the earliest average den entry date, the unusual variation among individual observations prevented statistical separation of this group median from any other. In more general terms, all females (46) denned significantly earlier (median = November 24) than the 16 males (median = December 10). The comparison was $Z = 2.32$, $P < 0.02$.

EMERGENCE DATES BETWEEN CLASSES

The median den emergence dates for males (March 26), females with yearlings (April 5) and barren females (April 8) were not statistically different, nor were those for females with cubs (April 15) and barren females. Females with cubs emerged from their dens significantly later than females with yearlings ($Z = 2.09$, $P < 0.02$) and males ($Z = 2.00$, $P < 0.03$). In more general terms, females with cubs had a significantly later emergence date than all the other 25 bears collectively for which the median date was April 2 ($Z = 3.19$, $P < 0.001$). Emergence data for all classes exhibited a normal distribution around the median (Figure 1).

DISCUSSION

Unlike Lindzey and Meslow (1976) or Jonkel and Cowen (1971), the present authors did not observe significant differences in the annual or composite den entry dates between adult and subadult groups. Moreover, no statistical differences were detected between subadults of the same or different sex, or between subadults and each adult reproductive class. It is possible that fragmentation of the data by age groups or calendar years so reduced the samples that real differences between den entry or den emergence dates were difficult or impossible to detect.

Despite significant differences in the average autumn (October-December) temperature, snowfall and snow depth (Table 3), there was no significant correlation between these variables and the onset of denning (Spearman rank correlation coefficients were, respectively: $r' = -0.1$, -0.1 and -0.3). The weighted average den entry date for all bears in 1979 (November 22) was the earliest observed during the four years that sufficient date were available. During the autumn of 1979, abnormally high temperatures (average = 2.2° C.) were accompanied by the least snowfall (17 centimeters) and average snow depth (1.60 centimeters) measured during the study. On the other hand, during the coldest and

TABLE 3. DEN-ENTRY DATE FOR BLACK BEARS AND AUTUMN WEATHER CONDITIONS IN THE CATSKILL REGION, 1976-1979.

Year	Den-entry date*	Autumn weather conditions§		
		Snowfall† (centimeters)	Average daily snow depth (centimeters)	Average temperature (degrees centigrade)
1976	December 8	77	6.29	−2.8
1977	November 23	112	12.04	0.4
1978	December 8	76	6.18	0.7
1979	November 22	17	1.60	2.2

*Weighted average date for all classes of bears.

§Autumn considered to be October, November and December.

†As recorded at the Slide Mountain weather station of the National Atmospheric and Oceanic Administration (climatological reports for October, November and December in 1976, 1977, 1978 and 1979).

snowiest autumns (1976, −2.8° C.; 1977, snowfall = 112 centimeters, average snow depth = 12.04 centimeters), the den entry dates were December 8 and November 23, respectively. These findings are contrary to those of Erickson et al. (1964) and Northcott and Elsey (1971) that weather, particularly heavy snow and/or low temperature induced denning.

Food availability and/or physical condition of the bears have been considered significant elements contributing to the regulation of denning among black bears (Spencer, 1955; Lindzey and Meslow, 1976; Willey, 1978). Physical indices of bear condition are collected during autumn hunts. However, hunting seasons were suspended in the Catskills in 1976 and 1977, thus precluding normal collection of data. The abundance of summer foods was believed to be relatively stable during the study, and pre-denning body-fat deposition was assumed to vary with the abundance of autumn mast. Although no attempt has been made to measure the abundance and distribution of mast, subjective evaluations have been recorded annually. Relative mast abundance was similar for all the years except 1976 when acorns were exceptionally plentiful. Perhaps the late denning observed in 1976 (weighted average for all bears = December 8) was in part a function of mast abundance that year. Late denning in 1978 (December 8) cannot be explained in the same manner. Early den entry observed in 1977 and 1979 (November 23 and 22, respectively) cannot be explained by a notable shortage of autumn foods.

Craighead and Craighead (1972) reported that female grizzly bears emerging with cubs were the last to leave their dens, i.e., after adult males, adult females and females with yearlings. The authors observed a similar pattern of emergence for females with cubs. Lindzey and Meslow (1976) also reported that females remained at the den site longer than other bears.

The timing of den emergence may be influenced by early-spring temperatures. For the three years when adequate emergence data were available (1977, 1978 and 1979), there was a non-significant positive correlation ($r' = 0.5$) between emergence and the combined monthly average temperatures for March and April. The coldest March-April occurred in 1978 (average = −1.2° C., significantly colder than in 1977 or 1979, Table 4). In that year the weighted average emergence date for all bears was April 14, the latest for the 3-year period. The remaining two years, 1977 and 1979, were warmer but not significantly different (1977 = 2.0° C.; 1979 = 1.6° C.). Weighted average emergence dates for these years were also very similar, i.e., April 7 and April 5, respectively. The small differences between temperatures and emergence dates in 1977 and 1979, and the late emergence observed in 1978, may indicate that a realistic relationship between spring temperatures and emergence dates does exist despite the lack of a significant correlation.

Table 4. Results of One-way Analysis of Variance Tests For Differences Between Years With Respect to Temperature, Snowfall and Snow Depth During Autumn and to Temperature During Spring§†

Comparison (years)	Lower bound	Difference in means	Upper bound
Autumn temperature (F-ratio = 7.990)			
1976 vs. 1977*	− 9.37230	−5.66848	−1.96465
1976 vs. 1978*	−10.0136	−6.30978	−2.60596
1976 vs. 1979*	−12.6495	−8.94565	−5.24183
1977 vs. 1978	− 4.34513	−0.641304	3.06252
1977 vs. 1979	− 6.98100	−3.27717	0.426651
1978 vs. 1979	− 6.33969	−2.63587	1.06796
Autumn snowfall (F-ratio = 2.200)			
1976 vs. 1977	− 0.464286	−0.146739	0.170808
1976 vs. 1978	− 0.312112	0.005437	0.322982
1976 vs. 1979	− 0.056677	0.260870	0.578417
1977 vs. 1978	− 0.165373	0.152174	0.469721
1977 vs. 1979*	0.090061	0.407609	0.725156
1978 vs. 1979	− 0.062112	0.255435	0.572982
Autumn snow depth (F-ratio = 15.110)			
1976 vs. 1977*	− 3.46469	−2.26087	−1.05705
1976 vs. 1978	− 1.16035	0.043478	1.24730
1976 vs. 1979*	0.644003	1.84783	3.05165
1977 vs. 1978*	1.10052	2.30435	3.50817
1977 vs. 1979*	2.90487	4.10870	5.31252
1978 vs. 1979*	0.600525	1.80435	3.00817
Spring temperature (F-ratio = 5.216)			
1977 vs. 1978*	2.01616	5.93443	9.85269
1977 vs. 1979	− 3.05761	0.860656	4.77892
1978 vs. 1979*	− 8.99204	−5.07377	−1.15550

§Tests at 0.95 level of confidence.

†Autumn = October-November; spring = March-April.

*Test indicates significant difference by exclusion of zero from confidence interval.

Rogers (1974) believed that emergence of bears in Minnesota was associated with temperatures higher than 10° C. and the accompanying rapid snowmelt. In the present study, such temperatures were observed on only three occasions during the two weeks preceding the median emergence dates (twice in 1977 and once in 1979). This suggests that, if a temperature threshold exists for bear emergence, it must be below 10° C. in the Catskill region of New York.

CONCLUSIONS

Estimates of the size and dynamics of bear populations are frequently derived from data for bear harvests. When hunting seasons occur during or after the denning period, such data may be influenced by the

chronology of den entry and emergence. Failure to recognize this leaves the wildlife manager vulnerable to underestimating populations and misinterpreting sex and age data.

These preliminary findings for the Catskill region of New York were applied in formulating the bear hunting seasons there in 1979 and 1980. These seasons were designed to allow a late-autumn hunting opportunity while increasing the probability of protection for pregnant females. The resulting increase in productivity was necessary to sustain the bear population in the region at the experimental level achieved through two consecutive closed seasons. Knowledge of denning chronology, as additional data are collected, should be increasingly important in planning bear management.

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AN ECONOMIC STUDY OF THE MUSKELLUNGE FISHERY IN NEW YORK[1]

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ABSTRACT

Data from a 1976-77 survey of licensed resident anglers in New York were analyzed to evaluate the annual recreational benefits of the muskellunge fishery. Participation in muskellunge fishing was significantly influenced by angler preferences, travel costs to angling sites, the proximity of alternative sites, and angler income. The net economic value of the fishery, on a per-day basis, was highest at the St. Lawrence County sites on the St. Lawrence River, while total annual benefits were greatest at the Jefferson County sites on the St. Lawrence River. Simple aggregation over the five muskellunge-fishing sites considered gave a total net annual value to licensed New York resident muskellunge anglers of $1.8 million in 1976, which would be $2.7 million in 1982 dollars. The local economic impact of expenditures by these anglers is also discussed.

The muskellunge (*Esox masquinongy*) is one of the most highly esteemed freshwater game fish in eastern North America, and New York's muskellunge fishery is widely known for producing large numbers of this trophy fish as well as individuals of record size. The principal muskellunge waters of the State are the St. Lawrence River, Chautauqua Lake and the Niagara River, which together accounted for 84 per cent of the statewide harvest in 1976-77. The present world record sport-caught muskellunge (69 pounds, 15 ounces) was taken from the St. Lawrence River in 1957. The State's only muskellunge hatchery is located at Chautauqua Lake and is a major factor in supporting the population there, but elsewhere populations are maintained by natural production. A unique attribute of the Niagara River is its importance as an urban recreation site for people from the cities of Buffalo and Niagara Falls.

Despite the popularity of the muskellunge fishery, there has been little research concerning its economic significance to either the angling population or the State as a whole. Earlier studies were limited to assessing local economic benefits from the Chautauqua Lake fishery (Horn, 1978) and recommending management policies for the long-term maintenance of the fishery in the St. Lawrence River (Panek, 1980). The present study was concerned primarily with estimating the net economic value of the muskel-

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lunge fishery, in terms of data from the St. Lawrence River, Chautauqua Lake and the Niagara River, to licensed resident anglers. In addition, the impact of angler expenditures on the regional economy was estimated. At the outset, it is important to say that other possible benefits from this fishery were necessarily omitted from consideration. Omission of data for out-of-state anglers and unlicensed anglers could be significant since quality muskellunge-fishing sites are few and may draw anglers from great distances.[3] In addition, there are several popular Canadian sites in the international waters of the St. Lawrence River and the upper Niagara River that were not considered. Individuals who used any of the sites for non-angling purposes, such as recreational boaters and tourists, were also not included. Others, while not at that time participating in the fishery, may value the option to do so in the future. The study also did not consider possible substitution between muskellunge and other fish species.

METHODS

Following is an outline of the conceptual approach of the study and a description of the methods that were used to evaluate the economic aspects of the fishery, including a discussion of the economic models and the data.

ECONOMIC VALUE OF OUTDOOR RECREATION

Unlike most goods and services, the value of outdoor recreational resources is not revealed automatically in the marketplace. Thus, information concerning such values must be imputed. Although there are several conceptual methods for estimating the value of the services produced by a recreational fishery, some are more appropriate than others in a given situation, while others would be incorrect under all circumstances. For example, the individual angler is usually assumed to pursue an angling experience for the satisfaction or welfare that it is expected to provide. From this perspective, the angler's willingness to pay for the angling experience would be the most appropriate measure of recreational value, and the net economic value of the experience would be the amount by which the angler's willingness to pay exceeds the actual monetary and time costs associated with the activity. Frequently, the expenditures of anglers for transportation, food and lodging, and equipment are used as an estimate of recreational benefits. While such measurements of expenditures may be useful for estimating regional economic impacts or for comparing different types of fisheries, they are incorrect as a measure of a fishery's net economic value to anglers. The value that should be sought is the net in-

[3]The National Survey of Hunting and Fishing (U.S. Department of Interior, 1972) estimated that, in the United States as a whole, there was 0.50 unlicensed freshwater angler for every one that was licensed. They represented juveniles, senior citizens and other persons exempted by various states from purchasing a license.

crease in economic worth beyond what would occur in the absence of a particular recreational angling opportunity.

The Travel Cost Method

The travel cost method has often been used to estimate the willingness of recreationists to pay for services at a recreation site. According to this method, which was first applied to outdoor recreation by Clawson (1959) and Clawson and Knetsch (1966), the economic value of a public outdoor recreational resource should be based on the willingness of users to incur costs to make use of the resource since this amount represents what they would be willing to pay for the resource rather than go without its use. The travel cost method assumes that users view the cost of travelling to the site as the price for use of its services, so that the demand for these facilities can be inferred from data relating the frequency of observed visits to travel costs.[4]

The travel cost method is a two-stage procedure for estimating net economic value. The first stage predicts participation rates for an outdoor recreation site as a function of travel costs and other determinants of participation.[5] This information is then used in the second stage to estimate the recreation demand curve for the site, showing the response of users to a hypothetical entrance fee (or "price") for use of the site. Users are assumed to respond to an increase in the entrance fee as individuals from greater distances did to an increase in the cost of travelling to the site (Clawson, 1959; Dwyer et al., 1977). With the travel cost approach, the net economic value of the resource in its current use is the amount that users would be willing to pay in excess of their actual expenses, which is equal to the area under the demand curve and above the level of actual travel costs as described by Clawson and Knetsch (1966).[6]

The general form of the first-stage equation for predicting visitation to an outdoor recreation site is

$$(1) \qquad V_{ij} = f(TC_{ij}, A_j, SE_i, TC_{ik}, A_k)$$

[4]Recent applications of the travel cost method contain factors other than travel costs as determinants of visiting a recreational site. Other influential factors include the availability and attractiveness of substitute sites, the quality of the site, and various socioeconomic considerations (Cicchetti et al., 1976).

[5]The participation equation is not identical to the demand function, though the terms are often used interchangeably. Observed participation can be assumed to equal demand only in cases where there are no capacity constraints at the site (Dwyer et al., 1977).

[6]A basic assumption of the travel cost method is that the costs of travelling to a site are exactly offset by the utility of travel and, therefore, there is no net benefit from the trip itself (Brown et al., 1965; Dwyer et al., 1977). That is, any net benefits that users receive from the recreational experience are associated with the site itself rather than the trip. If the utility of travel is assumed to be zero, the value thus calculated represents the net economic value of the recreational resource.

where

V_{ij} = number of visits from origin i to site j

f = a symbol representing an explicit functional relationship between V_{ij} and the explanatory variables

TC_{ij} = travel cost from origin i to site j

A_j = quality or attractiveness index for site j

SE_i = various socioeconomic characteristics of individuals in origin i

TC_{ik} = index of cost of travelling to substitute recreation sites

A_k = attractiveness index for substitute recreation sites

The cost of travelling from a place of origin to a site is a function of the variable monetary costs of automobile travel and the cost of travel time. Time costs should be included since, along with monetary outlays, time may be a constraint on recreational activity (Cesario, 1976; Cesario and Knetsch, 1970). Ordinarily, the value of travel time is assumed to equal a certain fraction of the wage rate (Knetsch et al., 1976).

Variables reflecting a site's attractiveness are included in the participation equation since site quality can be an important factor in explaining variation in visitation among sites. Measurements of quality that have been used in previous studies of recreational fisheries include angling success rates (Stevens, 1966), size of the recreation area (Ravenscraft and Dwyer, 1978), degree of crowding among participants (McConnell, 1977) and accessibility of the site (Cesario and Knetsch, 1976). Perceived water quality can also affect site attractiveness and thereby influence visitation (Bouwes and Schneider, 1979; David, 1971; Freeman, 1979).

Characteristics pertaining to the availability and attractiveness of substitute sites are also included in the model predicting recreation participation since they can affect visitation at a particular site.[7] Substitute sites may affect visitation in a number of different ways. If two sites are identical in all respects except for price (travel cost), users will tend to choose the lower-priced site. Sometimes sites act as complements to each other, since visits to a site that is near others can be looked upon as an investment in the possibility of performing recreational opportunities in a larger area. If the availability of substitutes is positively correlated with the distance between an origin and the site, decreased visitation from more

[7]The best examples of models that account for substitute sites are those of Burt and Brewer (1971), Cesario and Knetsch (1976), Cicchetti et al. (1976), Grubb and Goodwin (1968) and Gum and Martin (1975).

distant origins may be related to both the increased availability of substitutes and increased travel costs.

Certain socioeconomic variables are also likely to influence participation, though their effect may vary depending on the specific site and activity. For example, income and costs of travel time are positively correlated, so the net effect of including income as a determinant of participation is unclear. Education, age and preference variables are also frequently included as explanatory factors.

Data Used in Predicting Angler Participation

The study employed data from several sources, the major one being the 1976-77 New York resident angler survey (New York State Department of Environmental Conservation, 1981). This survey elicited responses from licensed resident anglers to numerous questions about fishing activities and expenditures, attitudes concerning fishery management, and angler preferences and characteristics. The questionnaire had been mailed to a random sample of 23,934 licensed resident anglers in the State, of whom 11,087 (46 per cent) responded. These data were used to determine angler characteristics, preferences for different fish species, site visitation rates, expenditures, success rates and other information necessary for appraising the muskellunge fishery.

The data for muskellunge were analyzed with respect to the St. Lawrence River, Chautauqua Lake and the Niagara River because these waters provide most of the muskellunge fishing in the State. In each case, all of the river or lake within a specific county was considered a fishing site. Therefore, the St. Lawrence River constituted two sites, Chautauqua Lake one site and the Niagara River two sites (Figure 1).

For the purpose of estimating the value of fishing for a particular species, the angler population considered should be limited to those who exhibit a certain level of interest in that species.[8]. Accordingly, the sample population included only those anglers who fished at one of the muskellunge-fishing sites and who also revealed a preference for muskellunge by spending time fishing for these fish (regardless of whether the angler actually caught a muskellunge).[9] Preferences for fish species were determined from a survey question asking the percentage of total angling time for the season that the angler spent fishing for each species. Thus, 259 observations provided the basis for the empirical analysis in this study.

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[8]In this study it was assumed that anglers distinguished between the various species of fish and that the purpose of spending a day at a muskellunge-fishing site was to fish for muskellunge. Support for this assumption is provided in the Department's final report on the angler survey (New York State Department of Environmental Conservation, 1981) which concluded that anglers fishing in New York waters were generally seeking a particular type of fish.

[9]The distinction between angler effort and success in catching fish is particularly important in the case of muskellunge since it is estimated that the capture of a legal muskellunge requires 100 man-hours of angling effort (Scott and Crossman, 1973).

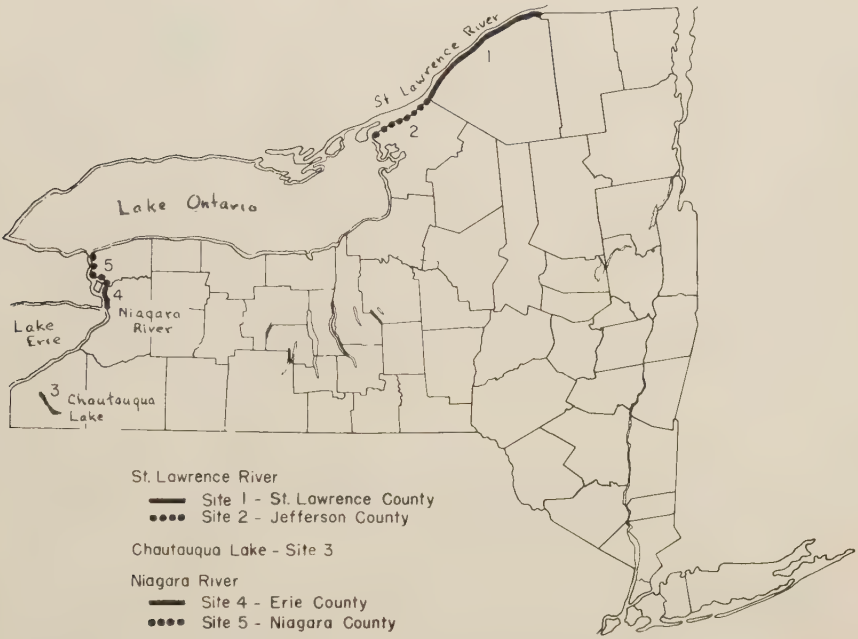

Figure 1. Map showing location of muskellunge-fishing sites studied.

The angler survey provided the number of days angling for muskellunge at each site and information on expenditures for the season, but it did not provide information about the actual number of visits, length of stay or cost per visit. Since counties were chosen as units to represent the origin of anglers, travel distances from the respective counties to each of the sites were determined by measuring the mileage from the largest town in each county of origin to the midpoint of each site (via primary roads insofar as possible). Examination of reported lodging expenditures indicated that anglers began to incur these expenses at a (one-way) distance of between 125 and 175 miles. Accordingly, anglers living within a 150-mile radius of a site were assumed to make a one-day trip at a price equal to roundtrip travel costs, while anglers living more than 150 miles from a site were assumed to make a two-day trip at a price per day equal to one-way travel costs. Variable monetary costs of travel were calculated by using the measured road distance and a constant of 10¢ per mile. Costs for travel time were based on travel at 50 mph and a value for anglers from a particular county equal to 35 per cent of the average hourly wage rate for muskellunge anglers in the sample from that county. The hourly wage rate was determined by dividing the reported annual income by 2,000 hours.

Since the sites in the study were not perfect substitutes, a variable was included to reflect site attractiveness. Because of data limitations, only fishing success rates and either the acreage of water or the relative extent ot

shoreline at each site could be used as attractiveness variables. The success rate at each site was calculated by dividing the total reported catch of muskellunge by the number of reported angler days. Acreage of water was defined as the total available acreage at each site and was estimated from data given by Greeson and Robison (1970). The shoreline variable was calculated as the extent of shoreline (in miles) at each site in relation to the total shoreline at all sites. The substitute for a specific site was defined in the model as the primary competing site for the one visited, i.e., Chautauqua Lake was the substitute for the St. Lawrence River sites, and the closer of the two St. Lawrence River sites was the substitute for Chautauqua Lake. The substitute price variable was defined as the cost of travel to the substitute site.

EMPIRICAL RESULTS

The empirical findings concerning the recreational value of the muskellunge fishery are presented with respect to angler participation, net economic value and local economic significance.

Angler Participation

The survey data were analyzed to provide information about the characteristics of muskellunge anglers and their visits to the different muskellunge-fishing sites (Tables 1 and 2). The characteristic that most distinguished the sites was the average one-way distance travelled by

Table 1. Characteristics of Resident Muskellunge Anglers in New York in 1976.

Characteristic	Mean	Standard deviation
Preference for muskellunge (per cent)	22.9	24.2
Experience in fishing for muskellunge (years)	28.9	13.9
Education (years)	13.3	2.9
Annual income (dollars)	18,700	10,400

Table 2. Extent of Area and Participation By Muskellunge Anglers At Each Site.

Site		Shoreline (miles)	Angler participation		
			Muskellunge taken per day	Distance travelled (miles one way)	
				Mean	Standard deviation
St. Lawrence River					
St. Lawrence County	(Site 1)	64	0.220	148	101
Jefferson County	(Site 2)	48	0.113	149	71
Chautauqua Lake	(Site 3)	42	0.075	53	79
Niagara River					
Erie County	(Site 4)	33	0.229	18	7
Niagara County	(Site 5)	26	0.237	6	3

anglers, which ranged from 6 miles for the Niagara County sites on the Niagara River to 149 miles for the Jefferson County sites on the St. Lawrence River. Success rates for the fishery ranged from 0.075 muskellunge per day at Chautauqua Lake to 0.237 per day at the Niagara County sites on the Niagara River.

The basic visitation function (1) was estimated by using several alternative specifications and functional forms before a final form was selected. While the results differed markedly for certain variables, it was found that, except for the Niagara River sites, travel costs to destination sites exerted a significant influence on visitation patterns (regardless of the functional form of the demand equation). The Niagara River sites were therefore excluded from further analysis.[10] The final specification of the participation equation was as follows

$$(2) \quad D_{ij} = f(TC_{ij}, I_i, P_i, S_i, TC_{ik})$$

In this and the other equations developed in this study, the following are the symbols and definitions for the variables used.

D_{ij} = total days angling at site j by respondents from county of origin i (dependent on definition of angler for this study, adjusted according to the angler's level of preference)[11]

f = a symbol representing an explicit functional relationship between D_{ij} and the explanatory variables

TC_{ij} = travel costs from county of origin i to site j (includes monetary and time costs)

S_i = number of anglers sampled in county i; represents constant percentage of angler population, across all counties, to whom questionnaire had been sent[12]

P_i = average preference level for anglers from county of origin i; preference level represents percentage of total angling time spent fishing for muskellunge

TC_{ik} = travel costs to primary competing site, i.e., Chautauqua Lake

[10]This is often found to be the case with urban recreation sites when using the travel cost method (Dwyer et al., 1977).

[11]This value for a given site was estimated by taking into account indicated preference for muskellunge and total days angling at the site. Each angler's activity was determined by weighting his total seasonal days at a muskellunge site, using his preference level for muskellunge and total time spent angling. Total muskellunge days at each site were determined by summing the data for all muskellunge anglers at the site.

[12]A variable representing sample size was included because previous studies had determined that population size is an important determinant of the number of trips generated (Cesario and Knetsch, 1976; Grubb and Goodwin, 1968). Angler population was used since this study was concerned with angling trips, which emanate from the population of anglers rather than the entire county population.

for the St. Lawrence River sites, and the closer of the two St. Lawrence River sites to the county of origin for Chautauqua Lake anglers

I_i = average level of income for anglers from county of origin i

ε = an error term

Education and income were found to be highly correlated and therefore could not be used jointly due to possible multicollinearity. Socioeconomic variables other than preference and income were excluded since both education and experience were found to be non-significant after testing them separately. Success rate, acreage and shoreline extent were tested as variables representing the quality or attractiveness of a site, yet none was found to be a statistically significant determinant of participation, possibly because there was insufficient variation among the sites with respect to these attributes.[13]

For empirical purposes, equation (2) may be reformulated as follows

$$(3)\ \log (D_{ij} + 0.8) = \beta_0 + \beta_1 \log TC_{ij} + \beta_2 \log S_i + \beta_3 \log P_i + \beta_4 \log I_i + \beta_5 \log TC_{ik} + \varepsilon$$

where the β terms are parameters to be estimated and ε is a random component.[14,15] The participation equations which were estimated are ordinary least squares regression estimates. The Glejser test was applied to the model and indicated that no heteroskedastic disturbance was present. The results for the first-stage equation (3), as applied to data for the St. Lawrence River and Chautauqua Lake sites, are presented in Table 3.

The estimates largely confirm *a priori* expectations, with most of the coefficient values being statistically significant at the 5 per cent level. The R^2 value of 0.49 for the muskellunge fishery means that changes in the specified independent variables explain 49 per cent of the observed change in the dependent variable D_{ij}, i.e., days of angling at site j for muskellunge by anglers from origin i. Most important for purposes of this study, travel

[13]The objective in specifying the final equation was to obtain reliable estimates of structural parameters (particularly for the travel cost variables) rather than a high coefficient of determination (r^2). This follows the suggestion of Gum and Martin (1975). Since the coefficients of the variables remained relatively unaffected whether the attractiveness variable was included or not, the attractiveness index was excluded from the final specification of the model.

[14]Both semilogarithmic and fully logarithmic forms of equation (2) were tested. It was generally found that the fully logarithmic model produced more significant and stable parameter estimates and greater over-all explanatory power than the semilogarithmic form, confirming the findings of others, e.g., Grubb and Goodwin (1968). For this reason the fully logarithmic model was chosen as the basis for deriving the results.

[15]All logarithms are natural logarithms, and "D_{ij}" is specified as "$D_{ij} + 0.8$" to avoid using the logarithm of zero (which is undefined).

TABLE 3. ESTIMATED PARAMETER VALUES FOR EXPLANATORY VARIABLES IN PARTICIPATION EQUATIONS FOR MUSKELLUNGE ANGLING AT ST. LAWRENCE RIVER AND CHAUTAUQUA LAKE SITES, ACCORDING TO DIFFERENT ASSUMPTIONS FOR COST OF TRAVEL AND TIME*

Parameter	Assumption for cost of travel and time§		
	10¢ per mile and 35 per cent of wage rate	15¢ per mile and 35 per cent of wage rate	10¢ per mile and 50 per cent of wage rate
Travel cost to site (TC_{ij})	−1.342 (−6.08)	−1.345 (−6.07)	−1.339 (−6.07)
Sample size (S_i)	0.686 (4.50)	0.685 (4.50)	0.686 (4.50)
Preference (P_i)	0.323 (3.36)	0.323 (3.36)	0.324 (3.36)
Income (I_i)	0.263†(0.99)	0.176†(0.70)	0.347†(1.24)
Substitute travel cost (TC_{ik})	0.280 (2.04)	0.278 (2.02)	0.282 (2.05)
Intercept	−2.820 (−1.45)	−1.665 (−0.86)	−3.498 (−1.78)
Correlation (F)	20.46	20.47	20.45
Reliability factor (R^2)	0.494	0.494	0.493

*Each equation has form of Equation (3) as given in text; dependent variable is days of muskellunge fishing.

§Figures in parentheses are t-values.

†Not significant at 5 per cent level.

costs from origin i to site j (TC_{ij}) were found to be a significant determinant of visitation patterns for anglers participating in the fishery. The results concerning substitute sites indicate that participation at any muskellunge site was positively related to the cost of going to its substitutes. That is, higher travel costs for substitute sites ordinarily cause greater participation at the site being studied (Burt and Brewer, 1971; Cicchetti et al., 1976). Of the socioeconomic variables tested, only preference and angler income were found to significantly affect angler participation.

It is possible that certain assumptions may influence the empirical results, particularly those affecting travel costs. In order to investigate the effect of the assumed cost per mile (10¢) and cost of time (35 per cent of wage rate) on the empirical results, different values for these components of travel costs were substituted in the participation equations. The results, also shown in Table 3, indicate that the effect and significance of the explanatory variables remain virtually the same. It can also be seen from the values of the parameters that, for the changes indicated, changes in mileage cost have a different effect than variation in the value of travel time. This is probably a result of the relationship between income and the cost of travel time.

NET ECONOMIC VALUE

The second stage of the travel cost procedure involved calculating a

hypothetical demand curve for the fishery from the results of the first-stage equation. The fishery demand curve can then be used to estimate the net economic value of the fishery. Since we were concerned with finding the economic value net of actual expenditures, it was necessary to determine how increases in cost would affect the level of participation. The level of all variables other than travel costs must be held constant when doing this. In the logarithmic model, changes in the level of the dependent variable depend not only on changes in cost but also on the level of the other variables. Since the level of these variables was different for each origin-site combination, a simplified equation had to be estimated for each combination by entering the level of all variables other than D_{ij} and TC_{ij} into the participation equation and solving the equation. For a given county-site combination, the equation reduced to

$$(4)\ \log (D_{ij} + 0.8) = C_{ij} + \beta_1 \log TC_{ij} + \varepsilon$$

where C_{ij} is a composite term representing the levels of all other variables and ε is an error term. This equation was then used to predict the degree of visitation as user fees were increased causing demand to approach zero.

Ordinarily, the second-stage demand curve for a certain site j is derived by increasing the travel costs to that site for each reduced-form equation by a hypothetical fee, and then summing the resulting participation estimates at each increment for all places of origin to provide the demand for the site. Taking the initial demand at a zero fee, the fee is increased (usually in one-dollar increments) until the demand for the site becomes zero. The demand at each increment of travel cost is a point on the demand curve for the site, and the area below this second-stage demand curve (when the data are plotted on a graph) represents the net economic value of the site.

This study used a variant of this approach in which the net economic value of a site is first derived for each origin and then aggregated for all origins to determine the site's net economic value as described by Dwyer et al. (1977) and McConnell and Norton (1976). This procedure was done for each of the two muskellunge-fishing sites on the St. Lawrence River and the one on Chautauqua Lake. The net economic value of a site to the anglers from each origin was obtained by estimating the area below the estimated demand curve and above the price actually paid for use of the resource (i.e., area ABC in Figure 2). Algebraically, this can be shown to be the definite integral of the demand equation between the limits of the current trip cost and the cost at which anglers from that origin would cease to visit the site.

Table 4 presents the estimated net economic value of the three sites to licensed muskellunge anglers in New York. Values were estimated both on a per-angler-day basis and as an annual total. The per-angler-day value

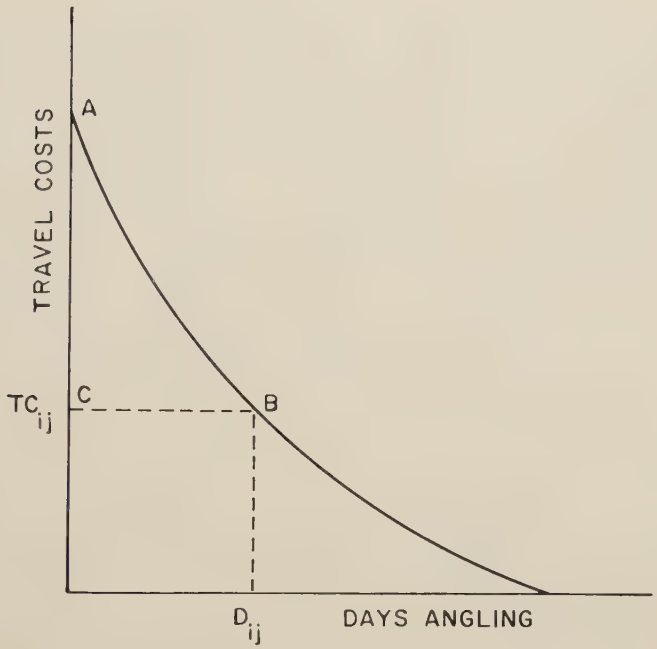

Figure 2. Economic value of a muskellunge-fishing site, in terms of demand curve representing relationship of days angling to travel costs.

TABLE 4. NET ECONOMIC VALUE OF THE ST. LAWRENCE RIVER AND CHAUTAUQUA LAKE MUSKELLUNGE FISHERIES TO NEW YORK RESIDENT ANGLERS IN 1976, ACCORDING TO DIFFERENT ASSUMPTIONS FOR COST OF TRAVEL AND TIME.

Site	Assumption for cost of travel and time		
	10¢ per mile and 35 per cent of wage rate	15¢ per mile and 35 per cent of wage rate	10¢ per mile and 50 per cent of wage rate
St. Lawrence River (Site 1)			
Per angler day	$ 32.92	$ 41.86	$ 38.87
Annual total	546,500	694,900	645,200
St. Lawrence River (Site 2)			
Per angler day	31.48	40.40	37.25
Annual total	547,800	703,000	648,200
Chautauqua Lake (Site 3)			
Per angler day	8.43	10.87	9.91
Annual total	645,200	648,200	643,200
Total	1,641,400	2,103,400	1,936,600

was determined by dividing the total net economic value per site by the estimated number of days. The annual total for each site was then calculated by multiplying the value per angler day by the actual number of angling days for all muskellunge anglers as given in Table 5.[16] The effect of alternative assumptions about travel and time costs on net benefits are also shown in Table 4.

The results varied widely from site to site and with different assumptions pertaining to the costs of travel and time. The variation among the fishing sites was due to differences in their distance from population centers, as well as to the attractiveness of alternative sites and the size of the human populations in the counties from which the anglers came. These factors influence the willingness of anglers to pay for services at the sites and also affect the number of anglers attracted to them. The highest values per angler day were estimated for the St. Lawrence County sites on the St. Lawrence River, largely reflecting a greater willingness to travel to reach these sites. Despite this, however, total net benefits were smallest at these sites. It should be noted that data for only three of the five top muskellunge-fishing sites in New York are represented in the results, and that the total net economic value of $1.64 million for the three sites in 1976 (under an assumed cost of 10¢ per mile and 35 per cent of wage rate) pertained only to licensed resident muskellunge anglers.[17] Also, changes in the cost of travel had a substantially greater effect on net economic value than did changes in the cost of travel time.

It was stated earlier that net economic value could not be estimated for the Niagara River sites by the travel-cost method because these sites attracted most of their anglers from neighboring urban population centers; consequently there was not enough variation in travel distances to yield meaningful results. To provide a more complete picture of the State's muskellunge fishery, however, the results for the other sites were extrapolated to give an approximate estimate of the Niagara River's value to anglers. Simple extrapolation of an average value for the other three sites would probably yield an overestimate for the Niagara River because of substantial differences in site and angler characteristics. Comparison of the data for all muskellunge anglers in Table 5 with those in Table 4 shows

[16]It should be emphasized that the total value for the fishing site equals the number of angler days at each site times the per-day value. Thus it is assumed that the angler day is entirely attributable to the site's muskellunge fishery. On the basis of this assumption, the angler sample for this study was limited to those who fished at one of the three sites and also indicated a preference for muskellunge. This is discussed further under "Data Used in Predicting Angler Participation" and in footnotes 8 and 11.

[17]The data in Table 4 suggest that the muskellunge fishery in Chautauqua Lake ranks considerably below that in the St. Lawrence River. Although true on the basis of participation by resident anglers, it should be pointed out that the St. Lawrence River sites draw the vast majority of their anglers from New York, while according to Horn (1978) Chautauqua Lake draws over 40 per cent of its muskellunge anglers and the majority of expenditures from out of state.

TABLE 5. VISITATION AND EXPENDITURES AT MUSKELLUNGE-FISHING SITES BY LICENSED RESIDENT MUSKELLUNGE ANGLERS IN NEW YORK IN 1976, ACCORDING TO RESIDENCE OF ANGLER*

Item§	St. Lawrence River		Chautauqua Lake	Niagara River		Total
	St. Lawrence County	Jefferson County		Erie County	Niagara County	
All muskellunge anglers						
Number of anglers	3,300	4,700	8,000	3,500	1,400	20,900
Number of angler days	16,600	17,400	64,900	15,900	6,200	121,000
Expenditures (dollars)						
En route	27,700	71,600	106,600	12,900	7,000	225,800
At site	84,600	211,000	300,500	46,900	10,700	653,700
Total	112,300	282,600	407,100	59,800	17,700	879,500
Expenditures per angler day (dollars)						
At site	5.10	12.13	4.63	2.95	1.73	5.40
Total	6.77	16.24	6.27	3.95	2.73	7.29
Muskellunge anglers residing outside county visited						
Number of anglers	2,300	4,100	4,500	600	100	11,600
Number of angler days	6,000	15,500	24,700	1,200	1,000	48,400
Expenditures (dollars)						
En route	25,600	66,200	85,100	1,000	4,400	182,300
At site	76,400	201,500	229,300	2,800	2,700	512,700
Total	102,000	267,700	314,400	3,800	7,100	695,000
Expenditures per angler day (dollars)						
At site	12.73	13.00	9.28	2.33	2.70	10.59
Total	17.00	17.27	12.73	3.17	7.10	14.36

*All figures are estimated and expanded from survey sample to represent State's population of licensed resident muskellunge anglers.

§Definitions as follows:

Anglers: total number who spent more than 0 per cent of their angling time fishing for muskellunge.

Angler days: total number spent at a given site fishing for muskellunge (see footnote 11).

Expenditures en route: total round-trip expenditures for all categories of travel expenses.

Expenditures at site: total expenditures at site, including gas, food, lodging, boat, guide and miscellaneous.

that in 1976 total expenditures at the three sites ($802,000) were roughly half the corresponding net economic value of $1,641,400. Lacking other information it would be reasonable to assume that the ratio of angler expenditures to net economic value would be the same for the Niagara River sites as that for the others. Based on this assumption, the net economic value of the Niagara River sites was approximately $159,000, and the total value of the five sites was approximately $1.8 million in 1976.

The results presented in Table 4 relate to the fishery's net economic value to licensed New York resident anglers in 1976. The current value of the fishery would be most accurately estimated by using current angler visitation and travel cost data. However, these data are not available and, since many factors such as travel costs, fishing restrictions due to pollution episodes and the like may have altered angler participation, it was decided that using current travel cost data with a simple extrapolation of 1976 visitation data to the current period would yield incorrect results. However, to provide an indication of the values in current (1982) dollars, the 1976 figures can be multiplied by 1.48, which represents the ratio of the two price levels (Federal Reserve Bank of St. Louis, 1982). Consequently, the net economic value for the five primary muskellunge-fishing sites in New York would be approximately $2.7 million in 1982 dollars. The range per site is from about $50,000 for the Niagara County sites on the Niagara River to $811,000 for the Jefferson County sites on the St. Lawrence River.

Local Economic Significance of the Muskellunge Fishery

From a regional perspective, a recreational fishery is of value because it contributes to local economic activity. These benefits from the fishery accrue to the people of the region as a whole (rather than just to the angling population) and are often referred to as secondary benefits. While incorrect as a measure of the fishery's net economic value, they provide an indication of the significance of angler expenditures to a regional or local economy.

Visitation and reported expenditures for the muskellunge fisheries by licensed New York resident muskellunge anglers in 1976 are shown in Table 5. These data are given separately for all muskellunge anglers and for those who fished outside their county of residence since anglers who resided in the county in which they fished would likely have incurred such expenses regardless of the fishery. At-site expenditures by anglers who fished outside their home county represent an increase that can be directly attributed to the fishery. Travel costs en route to fishing sites are distinguished from at-site expenditures because of difficulties in apportioning them among the respective sites. Expenditures for fishing equipment have been excluded from the data in Table 5 since they represent fixed outlays and cannot be apportioned among particular angling trips, sites or species.

Total expenditures reported by muskellunge anglers at the five sites were approximately $881,700 in 1976 ($1.3 million in 1982 dollars), of which $653,700 represented expenditures at fishing sites. There was substantial variation between sites. It is worth noting that Jefferson County, which had the largest values per day for at-site expenditures, did not have the largest net economic value per day. The Niagara River sites showed the lowest expenditures per day, possibly because most anglers were from the local area and fished only part of the day.

The most reasonable assumption is that the $512,700 for at-site expenses by anglers from other counties (Table 5) represented an infusion of spending directly associated with the regional muskellunge fishery. The current (1982) value of these 1976 at-site expenditures would be approximately $758,800. Using a multiplier of 1.5 to represent the effect of anglers' expenditures re-circulating within the region, the total amount of regional income attributable to expenditures by licensed resident anglers in the muskellunge fishery within the study region was approximately $769,100 in 1976, which converts to approximately $1,138,200 in 1982 dollars.

CONCLUSIONS

This study presents estimates of the economic significance of the muskellunge fishery in New York to licensed resident anglers and to the regional economy. Net economic value to anglers is the most appropriate measure of the fishery's contribution to economic welfare. Anglers' expenditures at the fishing sites indicate the significance of the fishery to local economic activity.

The results should be interpreted with caution for several reasons. First, there are possible direct benefits from the fishery in addition to those for licensed muskellunge anglers. There could be benefits to other anglers as well as to the non-angling population. Second, there are possible errors in the benefit estimates due to mis-specification of the underlying participation prediction equation. There are also possible errors relating to the survey data, or to use of the participation equation to estimate the fishery's net benefits, or to extrapolation of the 1976 results to the current period. Third, the results of this study are most meaningful for comparison on a per-day basis with those for other fisheries. It would be improper, for example, to add the values from this study of the muskellunge fishery to those for another fishery to approximate a total value for the two fisheries. In addition, there are some important conceptual issues concerning appropriate methods for evaluating recreational fisheries. One concerns the appropriate treatment of substitute sites. The value of a fishing site should be based on explicit consideration of substitutes for different species and geographic locations. Therefore, this study was focused on the muskellunge

fishery and considered only a limited number of alternative sites.[18] Another important conceptual issue relates to whether the value of one species can properly be determined in isolation from others that are part of the overall fishery at a given locality. To reduce the possibility of error, the angler sample in this study was limited to those who exhibited a certain level of interest in muskellunge. Nevertheless, this limitation should be recognized in interpreting the results.

Despite the limitations noted, the analysis should be useful for informational and policy purposes. Economic values are not of greater importance than other values, but information concerning a fishery's economic value should certainly be considered in establishing priorities for the use of society's natural resources.

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[18]Some fishery biologists might argue that even the muskellunge subspecies should be distinguished. For many years, three subspecies were recognized: the Great Lakes-St. Lawrence muskellunge; the Wisconsin or tiger muskellunge; and the Chautauqua or Ohio muskellunge. At present, however, the tendency is to treat them as a single variable species (Scott and Crossman, 1973). It could also be argued that the stocked muskellunge in Chautauqua Lake are not equivalent to the naturally reproduced muskellunge in the St. Lawrence River and Niagara River.

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PREDICTION OF WEIGHT AND REPRODUCTIVE RATES OF A WHITE-TAILED DEER POPULATION FROM RECORDS OF ANTLER BEAM DIAMETER AMONG YEARLING MALES[1]

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ABSTRACT

Antler beam diameter, weight and reproductive rates of white-tailed deer vary with the nutritional level of the population. The mathematical relationships of the mean antler beam diameter for yearling males in a population to the mean weight of yearling males and to the mean reproductive rates of females bred at different ages are given for data from New York. Linear regression equations representing these relationships are considered sufficiently accurate for calculating population dynamics and planning management programs.

Many biological functions of the white-tailed deer (*Odocoileus virginianus* are weight-dependent (Moen and Severinghaus, 1981) and may be expressed with equations based on weight (Moen, 1973, 1980). Reproductive rates, knowledge of which is essential for calculations of population dynamics, are one of these. Weight varies with the nutritional level of the population. Antler beam diameter also varies with the level of nutrition. Since records of antler beam diameter are readily obtained during the hunting season, this would afford an economical means of assessing the status of a deer population if a consistent correlation could be demonstrated. The relative costs of obtaining adequate samples of reproductive rates, body weights and antler beam diameters are about 30 to 10 to 1.

Antler beam measurements for yearling males were used by Sauer and Severinghaus (1977) to predict the reproductive rates of yearling females which, in turn, were used to predict the reproductive rates of adults for deer at the Seneca Army Depot in Seneca County, New York. The present authors have expanded the data base to include many other areas in the State and have derived linear regression equations for the relationship of antler beam diameter to the weight of yearling males in the fall and to the reproductive rates of females bred as fawns, yearlings and older adults.

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[1]The data reported here were gathered under New York Federal Aid in Fish and Wildlife Restoration Projects 1-R, W.35-R, W-28-R and W-89-R. Funds for analyzing the data and writing the report were provided by the New York State Department of Environmental Conservation under Project W-124-R and by the New York State College of Agriculture and Life Sciences at Cornell University.

MATERIALS AND METHODS

Data on antler beam diameter for yearling male deer were available for most of New York's deer range from 1950 to 1979, and weights, reproductive rates and antler beam diameters had also been recorded for deer at the Seneca Army Depot from 1957 to 1977.[2] Weight data for the State generally from 1945 to 1958 were summarized by Severinghaus (1979). Reproductive rates were reported by Cheatum and Severinghaus (1950) and Severinghaus (1954) for the period 1936 to 1954 and by Hesselton and Jackson (1974) for the years 1961 to 1968.

Antler beam diameter was measured in millimeters at a point between ½ and 1 inch above the burr using a thin-bladed caliper. The caliper blades were fitted between any papillae (knobs) that might be present so that only the beam was measured. When an antler was asymmetrical, two measurements at right angles were taken and the average was recorded. The recorded diameter was rounded to the nearest millimeter. For small antlers without a burr, the measurement was taken about 1 inch above the skull.

Linear regression equations were calculated, with antler beam diameter as the independent variable and weight and reproductive rate as the dependent variables. Mean values for the various data were used in the computations. Also, because most weight records are in terms of dressed weight, this was used in the analyses. For convenience, the following symbols were used to represent the variables considered.

YABD	antler beam diameter of yearling males
YDWP	dressed weight of yearling males in pounds
YDWK	dressed weight of yearling males in kilograms
FARR	reproductive rate of female fawns
YERR	reproductive rate of yearling females
ADRR	reproductive rate of older adult females
ELWK	estimated live weight in kilograms
FDWK	field dressed weight in kilograms

RESULTS

By means of the linear regression equations derived, mean antler beam diameter for yearling male deer may be used to predict mean dressed weight for yearling males, as well as mean reproductive rates for females according to whether they were bred as fawns, yearlings or older animals.

PREDICTION OF DRESSED WEIGHT

Antler beam diameter in millimeters and dressed weight in pounds were

[2]The data are recorded in various reports for New York Federal Aid in Fish and Wildlife Restoration Projects 1-R, Supp. C; W-28-R; and W-89-R.

TABLE 1. MEAN ANTLER BEAM DIAMETER AND MEAN DRESSED WEIGHT FOR YEARLING MALE DEER FROM FIVE REGIONS OF NEW YORK AND THE SENECA ARMY DEPOT.

Region	Antler beam diameter (millimeters)	Dressed weight	
		Pounds	Kilograms
Western	18.7	118.7	53.8
Adirondack periphery	17.8	109.0	49.4
Catskill periphery	16.8	105.4	47.8
Catskill central	16.0	95.7	43.4
Adirondack central	15.0	91.1	41.3
Seneca Army Depot			
1957-1958	16.4	94.9	43.1
1961-1962	18.2	109.5	49.7
1973-1977	20.0	117.2	53.2

compared for yearling males from five regions in the State and from the Seneca Army Depot (Table 1). For the Seneca Army Depot, data representing three levels of the deer population were used: 1957-58 when it was far above the carrying capacity of the range; 1961-62 when it was about at the carrying capacity; and 1973-1977 when it was below the carrying capacity. The antler beam diameters and weights reflected these population densities.

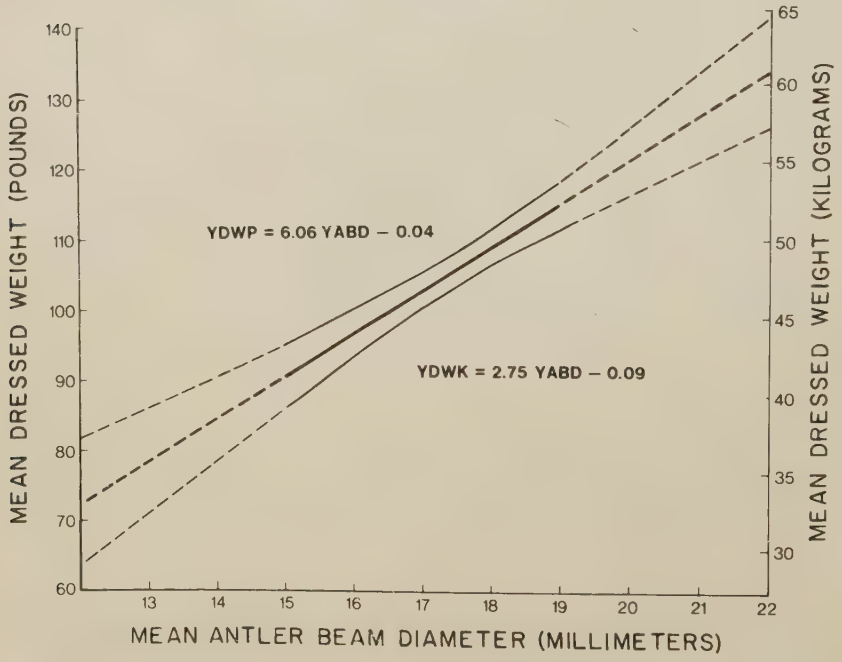

Figure 1. Relationship of mean dressed weight to mean antler beam diameter for yearling male deer. Heavy line represents regression; light lines represent 95 per cent confidence intervals for the slope. Dash lines indicate extrapolations.

The slopes of the regression lines for the five regions combined and the three population levels at the Seneca Army Depot were not different ($P < 0.05$), so the eight sets of data in Table 1 were combined. The resultant equation for calculating dressed weight in pounds as a function of antler beam diameter for yearlings was found to be

$$YDWP = 6.06YABD - 0.04$$

for which the coefficient of determination (r^2) was 0.89. For dressed weight in kilograms the equation was

$$YDWK = 2.75YABD - 0.09$$

for which the coefficient of determination (r^2) was 0.90. This relationship, with a 95 per cent confidence limit, for the slope and extrapolations beyond the 15- to 20-millimeter beam diameters measured is illustrated in Figure 1.

PREDICTION OF REPRODUCTIVE RATES

Antler beam diameters of yearling males and reproductive rates of females bred as fawns are correlated for the five regions in Table 2. On a

TABLE 2. MEAN ANTLER BEAM DIAMETER FOR YEARLING MALES AND CORRESPONDING MEAN REPRODUCTIVE RATES DURING TWO TIME PERIODS FOR FEMALES BRED AS FAWNS IN FIVE REGIONS OF NEW YORK*

Region	Antler beam diameter (millimeters)	Reproductive rates§		
		1936-1954†	1961-1968‡	Mean
Western	18.7	0.47	0.35	0.410
Adirondack periphery	17.8	0.24	0.35	0.295
Catskill periphery	16.8	0.25	0.19	0.220
Catskill central	16.0	0.17	0.05	0.110
Adirondack central	15.0	0.10	0.07	0.085

*Data from these regions for reproductive rates of adults could not be used because those for yearling females were not separated from those for older females.

§Embryos per female; all females considered whether embryos present or not.

†From Cheatum and Severinghaus (1950) and Severinghaus (1954).

‡From Hesselton and Jackson (1974).

regional basis, reproductive data were available only for fawns because in the records for 1936 to 1954 (Cheatum and Severinghaus, 1950; Severinghaus. 1954) yearlings were not differentiated from older females. However, the data for fawns were augmented by including the records for 1961 to 1968 (Hesselton and Jackson, 1974) after replotting them according to region. Also, the values for the two time periods are compared to determine whether the relationships were similar. Correlations for females bred as fawns, yearlings and older animals are given in Table 3 for the 10 ecological zones and in Table 4 for the Seneca Army Depot during 1957 to 1977. In the latter, the records are grouped according to increasing levels

Table 3. Mean Antler Beam Diameter For Yearling Males and Corresponding Reproductive Rates For Females Bred As Fawns, Yearlings and Older Adults For 10 Ecological Zones in New York*

Ecological zone	Antler beam diameter (millimeters)	Reproductive rates§		
		Fawn	Yearling	Older
Adirondack central	15.6 (3,673)	0.07 (70)	1.05 (43)	1.45 (118)
Adirondack periphery	18.9 (163)	0.78 (16)	. . †	1.71 (8)
Tug Hill	16.8 (149)	0.19 (16)	. . †	1.78 (10)
Mohawk Valley	17.8 (571)	0.21 (33)	. . †	1.87 (18)
Hudson Valley	17.2 (1,842)	0.22 (74)	1.37 (35)	1.92 (62)
Taconic Highlands	16.3 (882)	0.30 (15)	. . †	1.56 (22)
Hudson Highlands	16.3 (765)	0.00 (20)	. . †	1.60 (32)
Catskill central	16.0 (11,192)	0.05 (55)	1.04 (41)	1.41 (81)
Southern Tier	18.5 (27,606)	0.25 (246)	1.49 (155)	1.87 (236)
Lake Plains	20.4 (3,332)	0.61 (95)	1.82 (50)	1.75 (53)

*Figures in parentheses represent number of specimens.
§Embryos per female; all females considered whether embryos present or not. From Hesselton and Jackson (1974).
†Sample too small to be meaningful.

Table 4. Mean Antler Beam Diameter For Yearling Males and Corresponding Mean Reproductive Rates For Females Bred As Fawns, Yearlings and Older Adults For the Seneca Army Depot

Antler beam diameter		Reproductive rate*		
Mean (millimeters)	Years in which occurred§	Fawn	Yearling	Older
16.3	1957, 1958	0.00	1.07	1.68
17.2	1959	0.04	1.07	1.82
18.5	1960, 1961, 1973	0.22	1.45	1.86
19.7	1964, 1965, 1972, 1976	0.39	1.74	1.98
20.7	1967, 1970, 1971, 1974, 1975, 1977	0.40	1.77	1.93
21.7	1966, 1969	0.35	1.80	2.01

*Embryos per female; all females considered whether embryos present or not.
§In each case year represents fall of overwinter period; years 1962, 1963 and 1968 omitted because all data were not recorded.

in mean antler diameter and the years represented in each case are shown. Then the corresponding reproductive rates for these years are given. The regression factors are given in Table 5.

For females bred as fawns in the five regions, the slopes of the regression lines for reproductive rates in relation to the antler beam diameter of yearling males were not different for the two time periods ($P < 0.05$). Therefore the mean values were used. The corresponding slopes for the 10 ecological zones were not different ($P < 0.01$), nor were those for the Seneca Army Depot ($P < 0.05$). The data were pooled, and the equation for calculating the reproductive rate as a function of the antler beam diameter of yearling males was found to be

$$FARR = 0.078YABD - 1.135$$

for which the coefficient of determination (r^2) was 0.51.

For females bred as yearlings, the data were sufficient for only five of the

TABLE 5. REGRESSION COEFFICIENTS FOR RELATIONSHIP BETWEEN MEAN ANTLER BEAM DIAMETER OF YEARLING MALES AND MEAN REPRODUCTIVE RATES FOR FEMALES BRED AS FAWNS, YEARLINGS AND OLDER ADULTS

Area	Regression		
	Intercept (a)	Slope (b)	Coefficient of determination (r^2)
Fawn			
Five regions			
1936-1954	−1.233	0.0877	0.84
1961-1968	−1.367	0.0931	0.87
Mean	−1.283	0.089	0.96
Ten ecological zones	−2.060	0.134	0.66
Seneca Army Depot	−1.267	0.079	0.85
Yearling			
Five ecological zones*	−1.580	0.167	0.98
Seneca Army Depot	−1.530	0.158	0.91
Older			
Ten ecologocal zones	0.470	0.070	0.34
Seneca Army Depot	0.848	0.543	0.86

*Samples were sufficient for only five of the 10 ecological zones.

ecological zones. The slopes of the regression lines for these zones and those for the Seneca Army Depot were not significantly different ($P < 0.01$). Therefore, the data were combined, and the equation for calculating the reproductive rate as a function of the antler beam diameter of yearling males was

$$YERR = 0.151YABD - 1.344$$

for which the coefficient of determination (r^2) was 0.92.

For females bred as adults older than yearlings, data were sufficient for all 10 ecological zones. The slopes of the regression lines for these zones and the Seneca Army Depot were not significantly different ($P < 0.01$). Therefore, the data were combined, and the equation for calculating the reproductive rate as a function of the antler beam diameter of yearling males was

$$ADRR = 0.072YABD + 0.463$$

for which the coefficient of determination (r^2) was 0.55.

The regression lines and 95 per cent confidence limits for the slopes representing the mean reproductive rates for the three age groups are plotted in Figure 2.

DISCUSSION

That mean dressed weight can be derived from mean antler beam diameter for yearling deer makes weight estimates easy to obtain at low

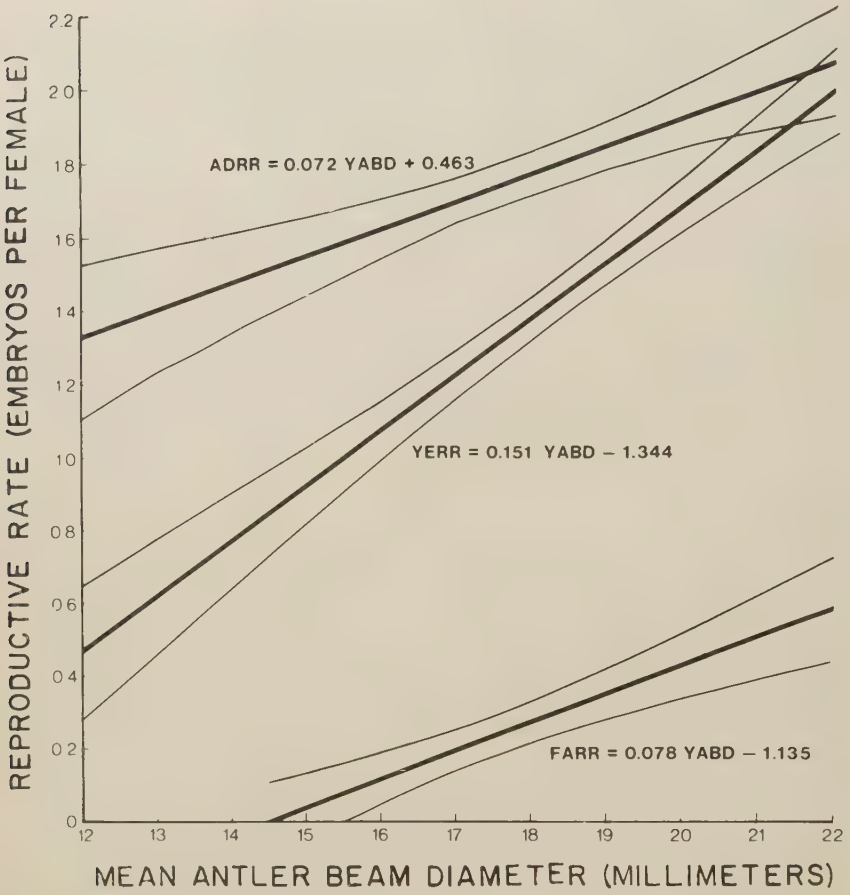

Figure 2. Relationships of mean reproductive rates for fawn (bottom), yearling (middle) and older female (top) deer to mean antler beam diameter for yearling males. In each case, heavy line represents regression; light lines represent 95 per cent confidence intervals for the slope.

cost. Dressed weight can be converted to live weight by a number of equations, four of which were listed by Moen (1980). The one most applicable for New York is that originally given by Severinghaus and Cheatum (1956)

$$ELWK = 1.89 + 1.249FDWK$$

Live weights may then be compared with time- and age-dependent estimates calculated from equations given by Moen and Severinghaus (1981). For a specific population, either the closest-fitting equation may be chosen, or interpolations may be made to derive a more appropriate one. The calculated values may then be used to determine weight and metabolic population structures as described by Moen (1981).

Derivation of mean reproductive rates for three age groups of females from mean antler beam diameters of yearling males seems particularly reliable as indicated by the rather narrow 95 per cent confidence limits for the regression-line slopes determined for different time periods and areas in the State. The steeper slope of the line for yearlings is a reflection of the greater potential of yearlings, than fawns or older adults, to respond to changes in range conditions. Deer produce larger antlers under good range conditions than under poor conditions, and more female fawns breed, although most bear only one young. On the other hand, most adult females bear two young. As range conditions improve, the proportionate increase in conceptions is essentially the same for fawns and adults, so that the slopes of the regression lines for the two age groups are not different. However, when range conditions improve from poor to good, the number of conceptions for yearlings rises from one to two and the corresponding regression line is steeper. When range conditions are excellent and antler beam diameters are the largest, yearlings conceive at nearly the same rate as adults (Figure 2). Under such conditions, an ample supply of nutrients allows them to reach the full reproductive potential of which they are genetically capable.

The data on which the foregoing calculations were made included few antlers with small diameters and few specimens with low dressed weights. In November 1981, a hunting season for deer in Harriman Park in Rockland County (N.Y.) resulted in records for 12 small yearling males. The mean antler beam diameter was 11.6 millimters ($S_x = 2.27$, $S_{\bar{x}} = 0.66$) and the mean dressed weight was 67.4 pounds ($S_x = 5.87$, $S_{\bar{x}} = 1.70$) which was close to the 70 pounds that would be derived from the equation for this age group given here.

Using the equations given here, values for the mean dressed weights for yearling males and the mean reproductive rates for females bred as fawns, yearlings and older adults were calculated (Table 6). From these values,

TABLE 6. VALUES FOR MEAN DRESSED WEIGHT OF YEARLING MALES AND MEAN REPRODUCTIVE RATES OF FEMALES BRED AS FAWNS, YEARLINGS AND OLDER ADULTS, AS CALCULATED FOR DIFFERENT MEAN ANTLER BEAM DIAMETERS OF YEARLING MALES

Antler beam diameter (millimeters)	Dressed weight		Reproductive rate*		
	Pounds	Kilograms	Fawn	Yearling	Older
12	72.7	32.9	0.00	0.47	1.33
13	78.7	35.7	0.00	0.62	1.40
14	84.8	38.4	0.00	0.77	1.47
15	90.9	41.2	0.04	0.92	1.54
16	96.9	43.9	0.11	1.07	1.62
17	103.0	46.7	0.19	1.22	1.69
18	109.0	49.4	0.27	1.37	1.76
19	115.1	52.2	0.35	1.53	1.83
20	121.2	54.9	0.43	1.68	1.90
21	127.2	57.7	0.50	1.83	1.98
22	133.3	60.4	0.58	1.98	2.05

*Embryos per female.

the corresponding weight and reproductive characteristics of a deer population may be estimated by recording only the antler beam diameter for a representative sample of the yearling males. Calculations of the metabolic structures of populations in relation to their weight and reproductive rates, as a basis for calculating the forage requirements of such populations, were discussed by Moen (1981). Since essentially all areas of the State were represented in deriving the equations, and since these relationships were the same for the different areas and time periods, the authors believe that the equations are reliable for calculating deer population dynamics and formulating management programs in New York.

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FALL MOVEMENTS OF BROWN TROUT IN LAKE ONTARIO AND A TRIBUTARY[1]

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ABSTRACT

Movements of radio-tagged brown trout during pre-spawning, spawning and post-spawning periods were studied in Lake Ontario and Sandy Creek in Monroe County (N.Y.) from September through November in 1980. Most of the tagged trout moved eastward in the lake after leaving Sandy Creek, but most of them eventually returned westward. Several made extensive east-west movements in Lake Ontario, but none ascended Sandy Creek farther than 2 kilometers. Until mid-October, most of the radio-tagged brown trout remained offshore in deep water during the day and moved inshore to shallow water at night. Water temperatures where fish with temperature-sensing transmitters were located generally corresponded to surface temperatures in shallow areas and averaged 11.5° C., well within the 10°-15° C. preference range of the species. However, as surface-water temperatures declined in late autumn, brown trout moved to deeper water where the temperature, although averaging 4° C., was warmer than that at the surface. During storms, the trout generally moved offshore to deeper waters or may have left the study area.

The recent introduction of Pacific salmon and the reintroduction of trouts and charrs (Parsons, 1973) have generated remarkable interest among anglers, recreational businesses and fisheries biologists throughout the Great Lakes region. Beginning in 1968, Lake Ontario has been stocked with chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), rainbow trout (*Salmo gairdneri*), brown trout (*S. trutta*) and lake trout (*Salvelinus namaycush*) as reported by the St. Lawrence-Eastern Ontario Commission (1978). Stocked salmonids are providing recreation and economic benefits in upstate New York (Brown, 1976; Panek, 1981), and an understanding of their ecology is important to maintaining a healthy fishery.

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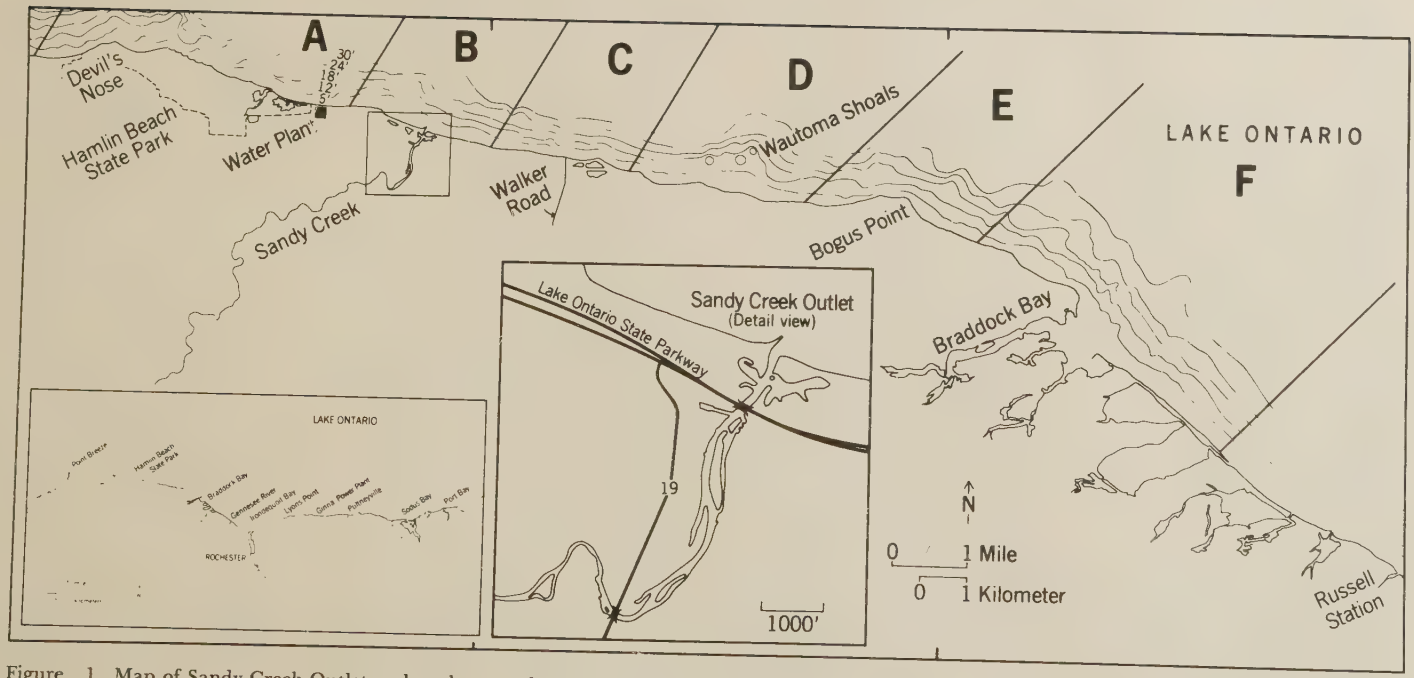


Figure 1. Map of Sandy Creek Outlet and study area along south shore of Lake Ontario.

Large numbers of brown trout are stocked annually in Lake Ontario by the State Department of Environmental Conservation (LeTendre, 1980), and it is currently the salmonid species caught in the greatest numbers by anglers (Panek, 1981). While there is some evidence for anadromous spawning populations of brown trout in Canadian tributaries of Lake Ontario (R. Desjardine, Ontario Ministry of Natural Resources, personal communication), such spawning in south-shore (U.S.) tributaries is nil (Abraham, 1980). Establishment of natural salmonid reproduction in at least some of the south-shore tributaries would be a great aid to fishery management. Therefore, the authors examined the movements (and associated environmental factors) of brown trout during the pre-spawning, spawning and post-spawning periods in Lake Ontario and Sandy Creek, a major tributary (Figure 1) in Monroe County (N.Y.), during the fall of 1980. Large numbers of brown trout are stocked annually in the vicinity of Hamlin Beach State Park, 5 kilometers west of Sandy Creek.

The region of Lake Ontario studied is typical of the western basin as described by Jenkins (1980) and is characterized by sharp increases in depth offshore, relatively little substrate structure and considerable private home development, mixed with wetlands, along shore. Although larger than other local tributaries, Sandy Creek is typical with shallow waters, summer temperatures above the optima for salmonids and considerable residential/agricultural development along its banks.

METHODS AND MATERIALS

Eight brown trout weighing from 2.3 to 5.1 kilograms were captured between September 19 and November 8 in the lower reaches of Sandy Creek, using a pontoon boat equipped with electroshocking booms and a DC generator. Using an MS-222/Quinaldine mixture, the fish were anesthetized on board in an aerated tank. Each was measured and weighed and its sex was determined from external characters. A numbered Floy anchor tag and an externally mounted, side-saddle, temperature-sensing radio-transmitter (Haynes, 1978; Ross et al., 1979) were attached to each trout. The transmitters, encased in epoxy, were cylindrical (1.8 × 8 centimeters) and weighed about 30 grams in water. They were attached by three wires inserted under the dorsal fin and were tied against padded plastic plates (Figure 2). After being tagged the trout were placed in an aerated recovery tank and were released after righting themselves and swimming actively.

The electronic equipment used was designed and built at the Cedar Creek Bioelectronics Laboratory of the University of Minnesota. Receivers operated at 53 MH_z and transmitters were separately identifiable. Fish were tracked by boat equipped with a directional Yagi antenna, along shore with a truck on which a Yagi antenna was mounted and on foot along Sandy Creek with a hand-held loop antenna. The methods followed

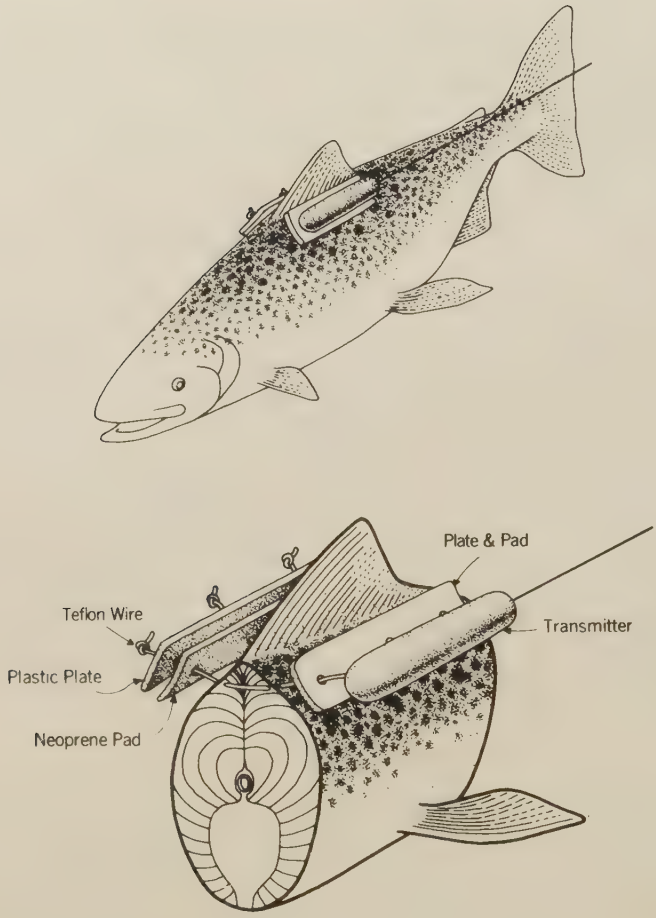


Figure 2. Diagram of manner in which radio transmitters were attached to brown trout.

those described by Winter et al. (1978). Tracking in Lake Ontario was limited to the nearshore area from Point Breeze eastward to the Genesee River, while that in Sandy Creek was done primarily below the Route 19 bridge (Figure 1).

RESULTS AND DISCUSSION

Until mid-October, brown trout moved offshore to deep water during the day and inshore to shallow water at night. This pattern, repeatedly displayed by the radio-tagged fish (and other salmonid species incidentally encountered during electroshocking), was so definite that all capture and most tracking activities were conducted between sunset and sunrise in September and October. The six brown trout that were radio-tagged prior to November left Sandy Creek for Lake Ontario before or during the first

sunrise after tagging. One fish remained motionless in Sandy Creek for 7 hours after being tagged, and then moved quickly out of range into the lake as the sun rose. The two fish that were tagged in November were both gravid and remained in Sandy Creek for 1 and 3 days, respectively. They probably spawned less than 2 kilometers upstream and then moved to Lake Ontario.

Day/night and offshore/inshore movement patterns were also observed for ultrasonically tracked brown trout in Airthrey Loch in Scotland (Young et al., 1972). The same study revealed peak activity periods at dawn and dusk. These peaks were later found to coincide with maximum feeding activity among brown trout (Oswald, 1978).

To depict movements of individual fish, a diagram of the study area was prepared showing key locations and their relative distances apart. The positions recorded for each of the tagged brown trout were plotted on this base map in sequence of occurrence (Figures 3 to 10). The date and time of occurrence for each position are also shown. Vertical distances of the tracking lines from the shoreline, as represented on these maps, are not indicative of the actual distance a fish was from the lake shore. During the study, fish from which radio signals could be detected were generally less than 2 kilometers offshore.

After leaving Sandy Creek, six of the eight radio-tagged brown trout moved eastward. Fish 293 (Figure 3) showed the simplest pattern of eastward movement. Five of these six fish returned west. Fish 323 (Figure 4) and Fish 343 (Figure 5) showed the simplest pattern of westward return, although the transmitter from Fish 343 was ultimately recovered in the fall of 1981 at a stream mouth 65 kilometers east of Sandy Creek. The authors believe that the initial predominance of eastward movement was related to the easterly flowing shore currents in this region of Lake Ontario as described by Jenkins (1980). However, two, Fish 175 (Figure 6) and Fish 214-B (Figure 7), initially moved west after leaving Sandy Creek.

Three brown trout, tagged early in the study, made repeated movements between Hamlin Beach State Park and Braddock Bay, up to 22 kilometers per day. Fish 275 (Figure 8) displayed the simplest pattern. Fish 214-A (Figure 9) returned to the mouth of Sandy Creek before being caught in mid-October by an angler at Hamlin Beach State Park, but the authors do not believe it spawned in Sandy Creek. Fish 113 showed the greatest variety of movements (Figure 10). Not only did this trout provide the greatest number of observations over the longest period of time, but it also moved the farthest west and farthest east, made the greatest number of east-west reversals and spent considerable time off Hamlin Beach State Park. It returned to Sandy Creek in late October where it was snagged and released twice by anglers and then either died or lost its transmitter.

After late October, the trout moved offshore to deeper water and became increasingly difficult to find due to attenuation of radio signals as

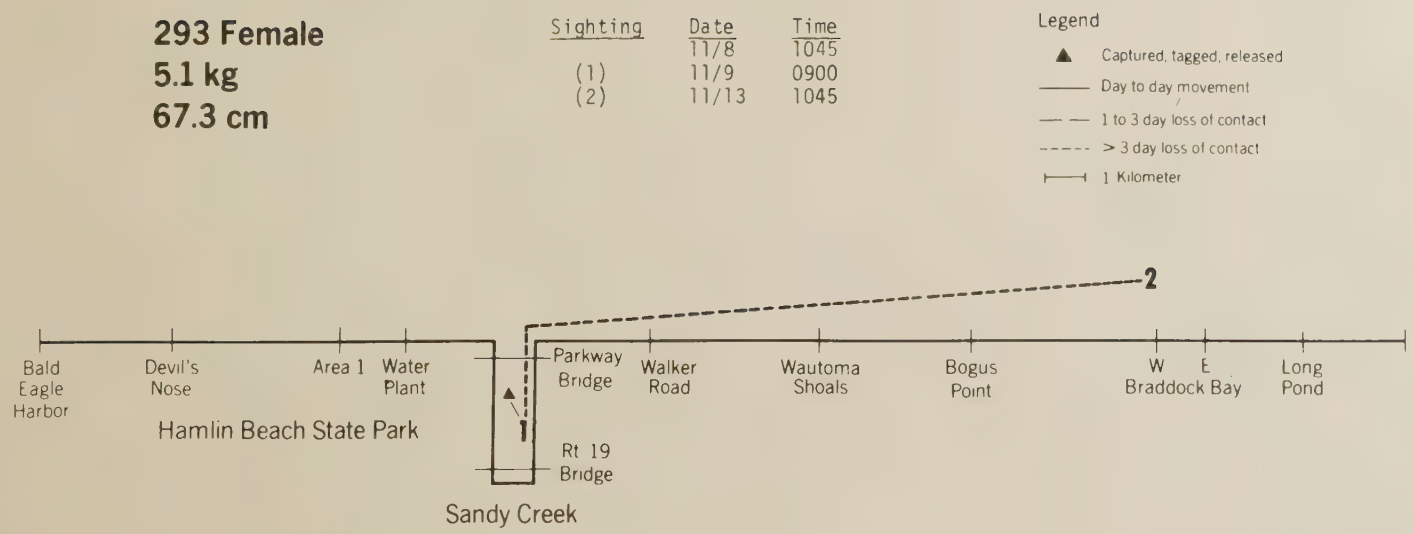


Figure 3. Recorded movements of Fish 293.

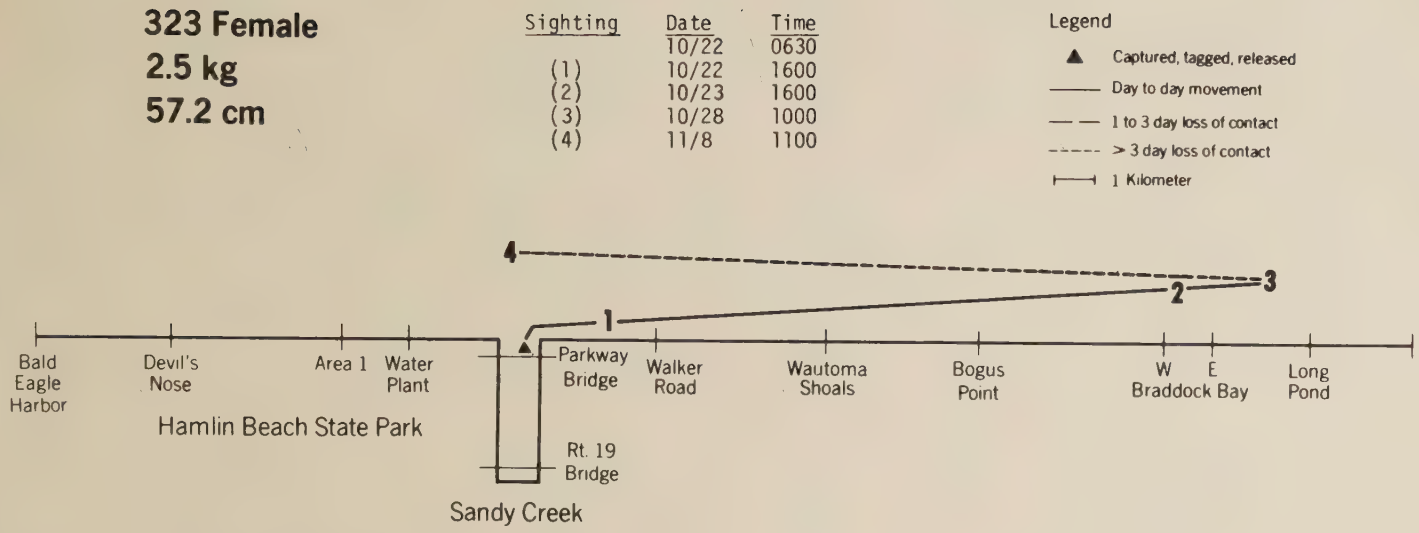


Figure 4. Recorded movements of Fish 323.

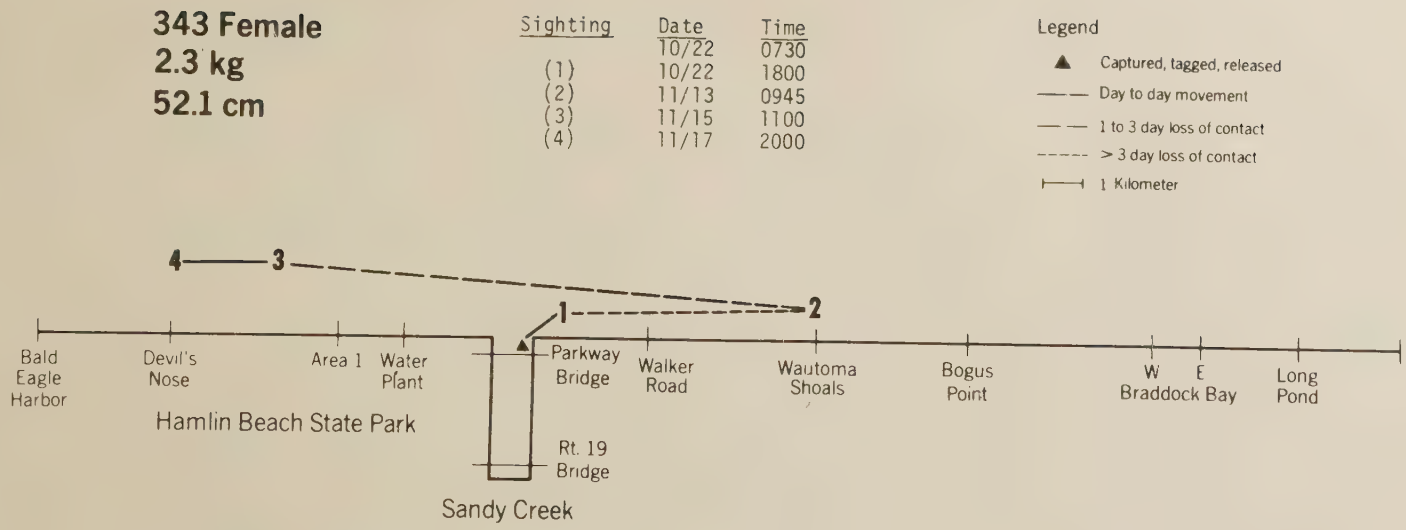


Figure 5. Recorded movements of Fish 343.

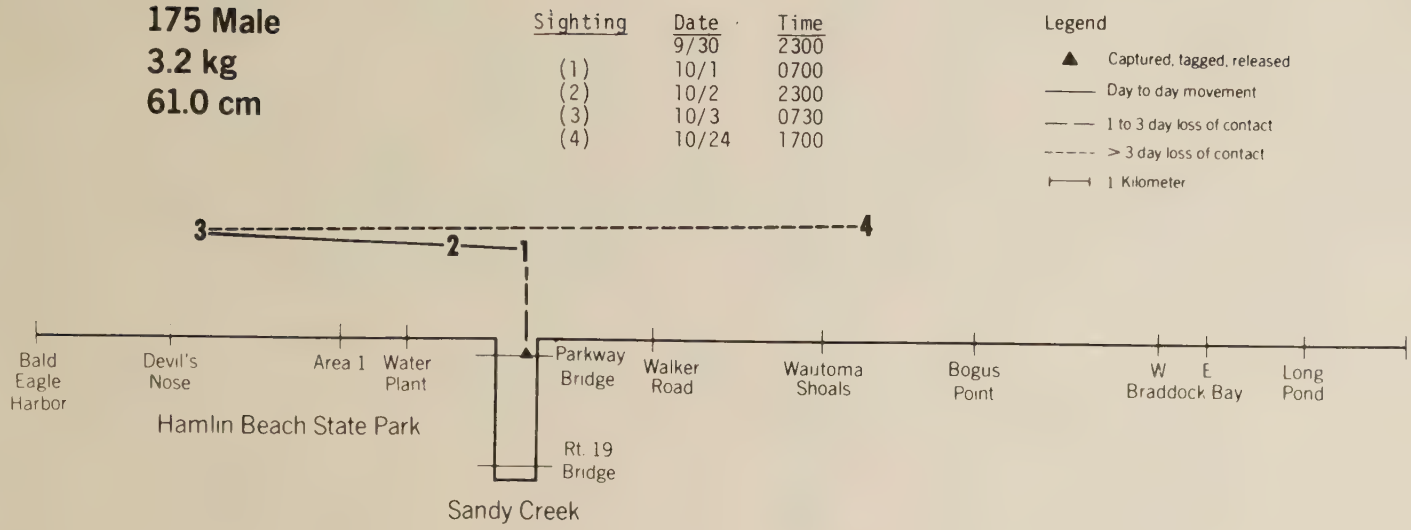


Figure 6. Recorded movements of Fish 175.

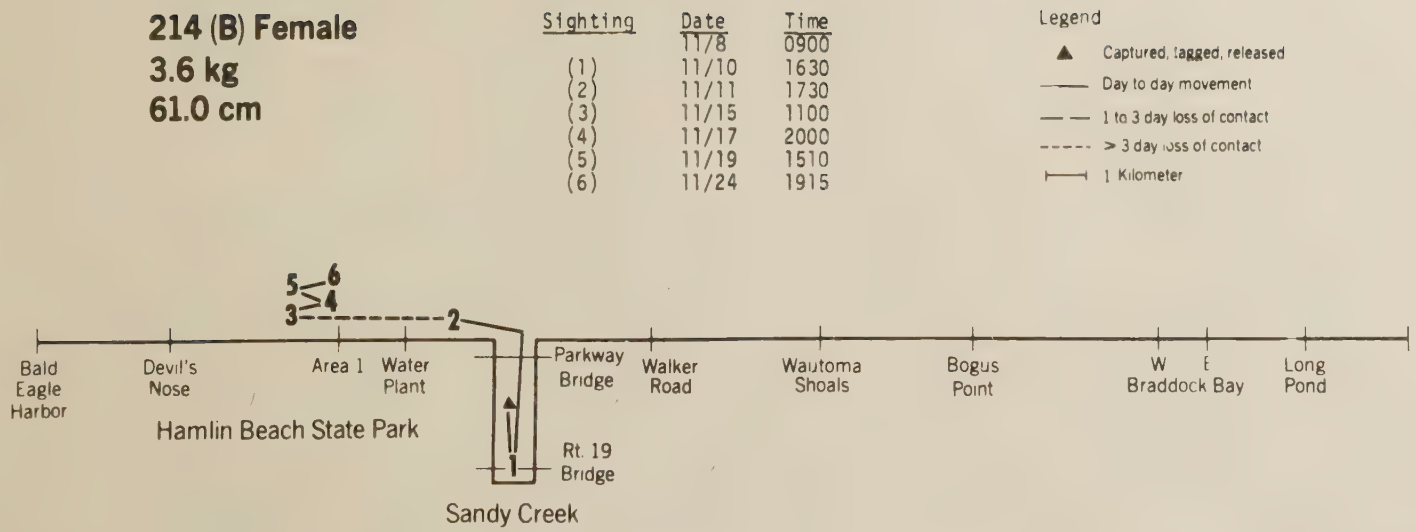


Figure 7. Recorded movements of Fish 214(B).

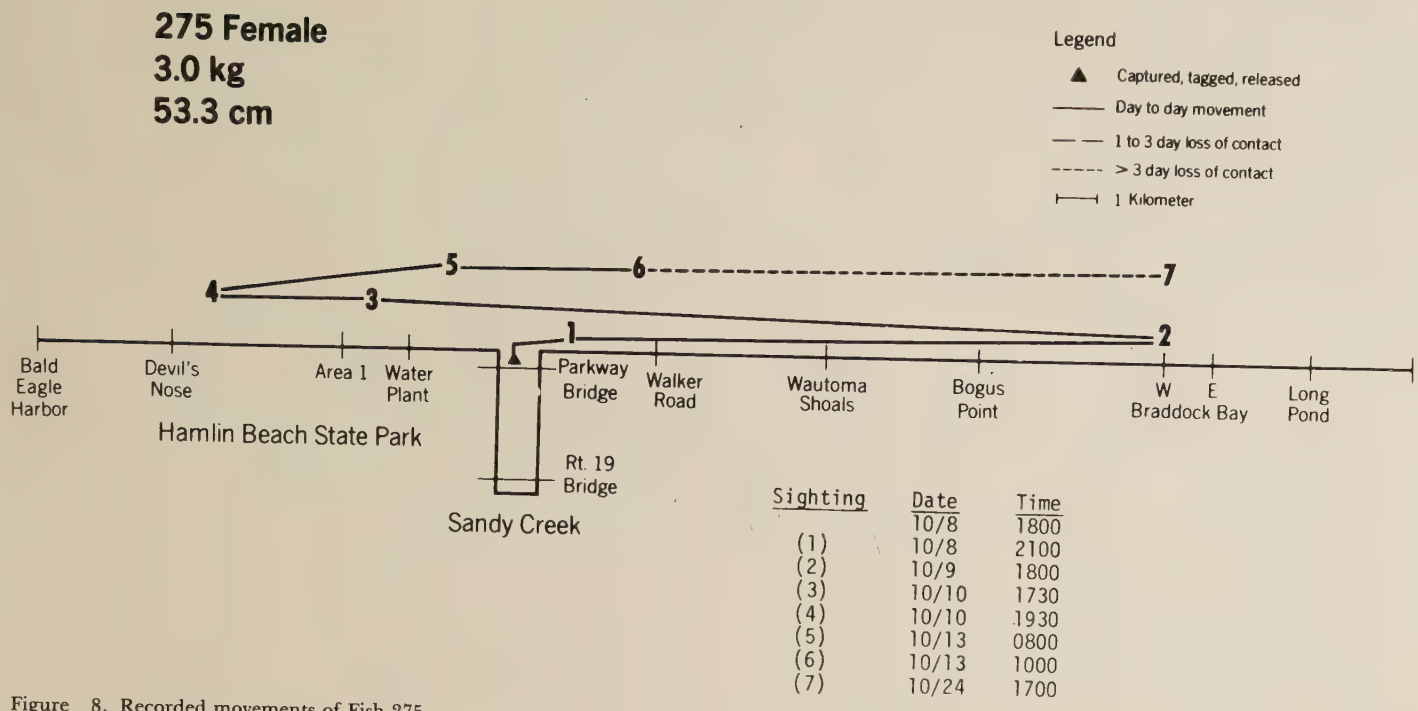
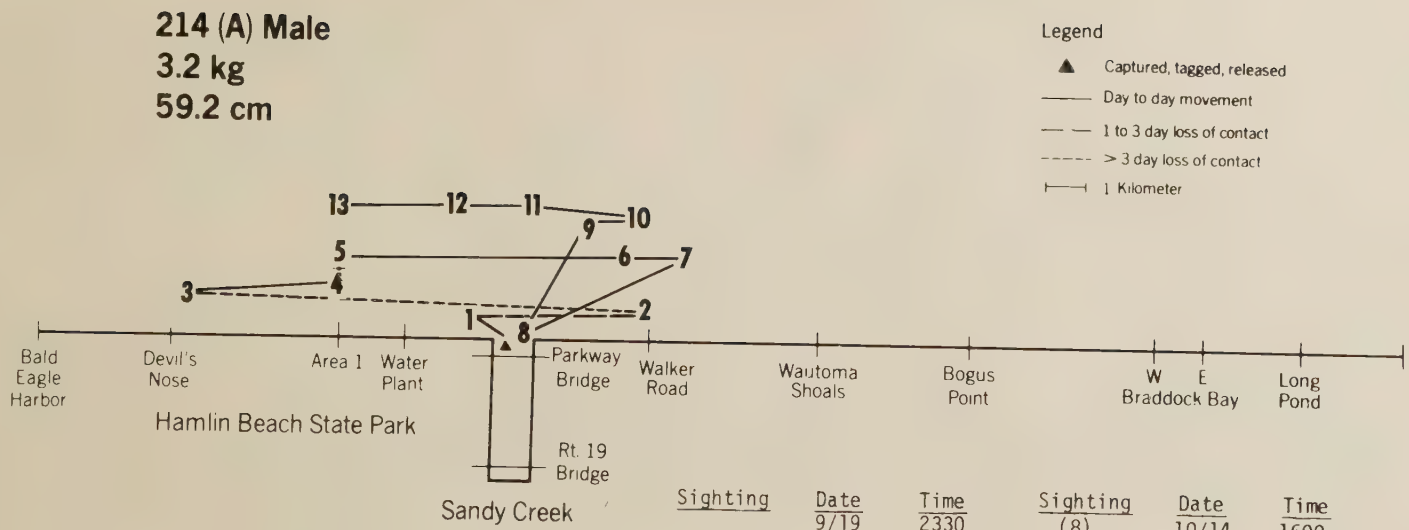
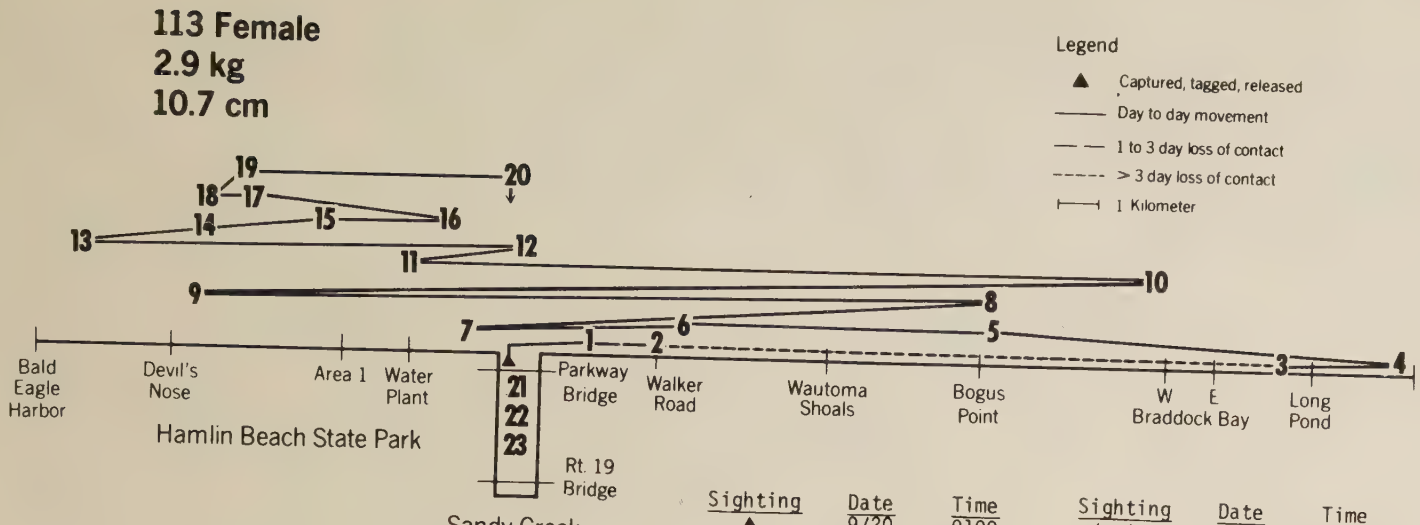


Figure 8. Recorded movements of Fish 275.



Sighting	Date	Time	Sighting	Date	Time
	9/19	2330	(8)	10/14	1600
(1)	9/20	0330	(9)	10/15	1500
(2)	9/21	2330	(10)	10/15	1630
(3)	10/5	1600	(11)	10/16	1230
(4)	10/6	2100	(12)	10/16	1400
(5)	10/7	2130	(13)	10/17	1530
(6)	10/9	2030	(14)	10/18	1500
(7)	10/13	1100			

Figure 9. Recorded movements of Fish 214(A).



Sighting	Date	Time
▲	9/20	0100
(1)	9/20	2300
(2)	9/22	2300
(3)	10/1	0200
(4)	10/1	0300
(5)	10/1	2300
(6)	10/2	0300
(7)	10/2	0730
(8)	10/3	0300
(9)	10/4	0600
(10)	10/5	1700
(11)	10/6	2000
(12)	10/8	2000

Sighting	Date	Time
(13)	10/9	2145
(14)	10/9	2315
(15)	10/10	1750
(16)	10/13	0800
(17)	10/13	1100
(18)	10/14	1500
(19)	10/16	1200
(20)	10/21	1700
(21)	10/22	1300
(22)	10/28	0730
(23)	10/30	2100

Figure 10. Recorded movements of Fish 113.

the depth of the fish increased. The last fish location was recorded in late November. Only two tagged trout (Fish 113 and 214-A) re-entered Sandy Creek after leaving, and periodic surveys of the stream confirmed that none of the radio-tagged fish moved upstream beyond the Route 19 bridge (Figure 1).

Brown trout behavior dictated tracking schedules. Until mid-October fish were tracked only at night. In late October and early November, as the trout spent increasingly more time near shore during the day, tracking crews alternated monitoring fish among mornings, afternoons and evenings (often tracking during two such periods a day). After mid-November, tracking was done every other day. The usual procedure was to track each day by boat or truck at standard locations 1 kilometer apart long shore from Devil's Nose to East Braddock Bay. The dash lines in Figures 3 to 10 represent actual tracking periods during which a particular fish could not be located. On several occasions tracking was extended as far as Point Breeze (30 kilometers west of Devil's Nose) and the Genesee River (15 kilometers east of Braddock Bay) to check for tagged fish beyond the usual tracking area, but such strays were found only twice (Figures 4 and 10). The authors believe that most of the tagged brown trout remained in the study area, but frequently were too deep to monitor, especially as winter approached.

To determine possible areas of concentration, the study area was arbitrarily divided into six zones (Figure 1). The number of fish days spent in each zone (Figure 11) show that the tagged trout tended to congregate off Hamlin Beach State Park. Although the park is 3 to 9 kilometers west of where the fish were initially captured and released, half the day-to-day tracking locations were in the Hamlin Beach area despite about equal searching times in each zone. These observations suggest a homing orientation to waters off Hamlin Beach State Park. Such orientation is supported by the fact that Fish 133, 175, 214-A and 343 had fin clips indicating that they were hatchery raised and had been stocked at Hamlin Beach by the State Department of Environmental Conservation in the spring of 1979 (W. Abraham, personal communication). Fish 214-B was stocked in 1979 at Sodus Bay (80 kilometers east of Sandy Creek) and three brown trout were unmarked.

The concentration of brown trout near Sandy Creek, the major source of flowing water in the study area, was not surprising. Counts there (Figure 11) do not include the records for the initial capture and release of the eight tagged trout. Only two of the fish returned to Sandy Creek. If these fish did spawn, they did so on muddy bottoms unsuitable for successful reproduction. Extensive electroshocking indicated that hundreds of brown trout (plus lake trout, rainbow trout and coho salmon) occupied the mouth and first kilometer of the stream, particularly at night, yet radio-tagged brown trout never moved upstream beyond the Route 19 bridge. This sug-

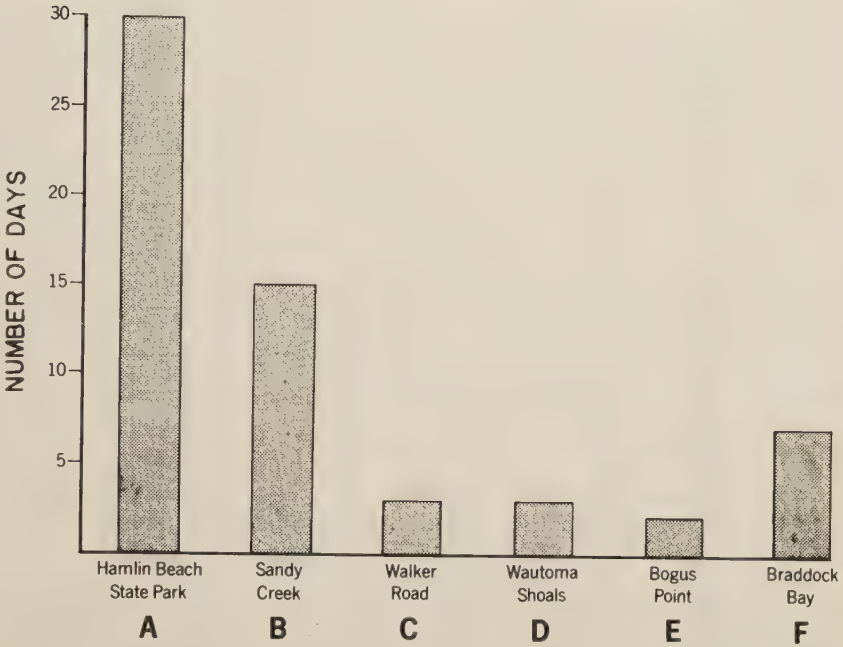


Figure 11. Number of fish days spent in each zone of the study area by the tagged brown trout.

gests that brown trout largely failed to use the several miles of stream above this bridge that were suitable for salmonid spawning. Braddock Bay was also important to the tagged fish. Apparently the substrate structure near the bay or the outflow of Salmon Creek was attractive to brown trout.

The total distance travelled (Figure 12) by the tagged fish ranged from 9 to 163 kilometers. However, these distances represent minima, as they are merely the sum of the distances between the recorded locations shown in Figures 3 to 10. Except for two fish, the total distance travelled by an individual trout was directly proportional to the length of time it was tracked. The importance of the total distance travelled is that it shows that brown trout move substantial distances along shore in autumn.

Average distances moved by fish on occasions when they were tracked on successive days ranged from 2 to 17 kilometers (Figure 12). The average distance moved per day is probably more useful in evaluating brown trout behavior and suggests frequent substantial daily movements by individual fish. However, sample sizes for this datum were small.

Several environmental variables may affect brown trout movements. A chi-square analysis showed that fish were located significantly ($P < 0.05$) more often on days when rainfall was less than 2.5 millimeters despite roughly equal tracking effort under rainy vs. non-rainy conditions. A severe wind and rain storm that dropped 2.5 centimeters of rain on Oc-

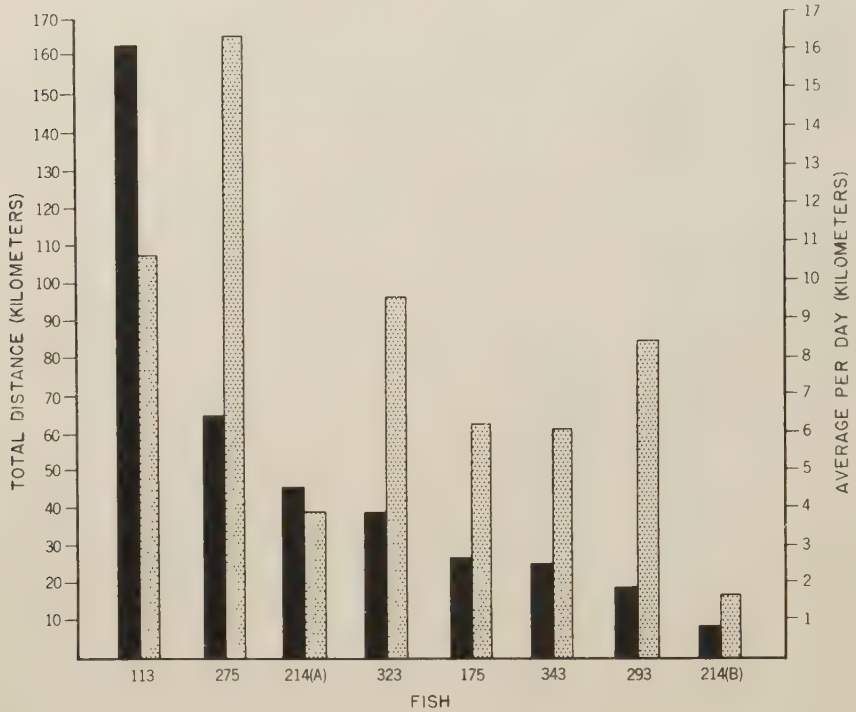


Figure 12. Total distance travelled (solid bars) and average per day for tracking records on successive days (stippled bars) for individual brown trout.

tober 25 affected our ability to locate fish. Two trout (Fish 175 and 275) that had been located on October 24 were never found again. Several others were not found again until several days after the storm. It seems probable that brown trout either dispersed to deeper waters during and after the storm or moved beyond the study area.

The temperature-sensing transmitters provided water temperatures within ± 0.2° C. where fish were located (Ross et al., 1979). In the present study, temperatures at the points where the tagged trout were located were compared with temperatures recorded at the intake pipe (1 kilometer offshore and 8 meters deep) of the Brockport Water Treatment Plant (Figure 1) and with surface temperatures recorded by the tracking crews. Sign tests (Snedecor and Cochran, 1972) revealed that in September and early October brown trout significantly more often inhabited water warmer than that at the treatment plant intake, while in late October and early November the reverse was true ($P < 0.01$). In both cases this meant that brown trout occupied areas near shore, as surface waters there were warmer than those at the intake in September and early October and colder after that. By late November, the tagged fish were inhabiting deeper, 4° C. waters which were warmer than the surface waters.

The findings of this study and others (c.f., Abraham, 1979) indicate that brown trout occupy inshore areas of Lake Ontario during spring and autumn when water temperatures do not exceed the thermal tolerance of the species. In summer, well before water temperatures exceed this level (approximately 26° C.), they retreat to deeper (cooler) water offshore. Abraham (1979) showed that brown trout in Lake Ontario had a close association with the bottom and occupied a temperature range of 10° to 15° C. during the summer. Reynolds and Casterlin (1979) found that brown trout under laboratory conditions preferred a temperature range of 10.3° to 13.7° C. In the present study, brown trout were recorded in waters ranging from 3.6° C. (November) to 18.4° C. (September), with a daily mean of 11.5 ± 3.9° C. Thus, optimum temperatures for brown trout in Lake Ontario lie in the 10° to 15° C. range, and fish can be expected to occupy such areas if forage, light and other conditions are suitable.

Of importance to fishery management is the presence of all salmonid species near shore at night in the fall. Brown trout, rainbow trout, lake trout and Pacific salmon are within casting distance from shore after dark and should be accessible to anglers, especially in September and October before feeding slows or terminates with the onset of physiological changes associated with spawning. Also, the data indicate that few brown trout ascend south-shore tributaries of Lake Ontario far enough to spawn in suitable areas. It appears that stocking must remain the major source of brown trout for this part of Lake Ontario.

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BIOLOGY OF THE NORTHERN PIKE IN THE UPPER NIAGARA RIVER WATERSHED[1]

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ABSTRACT

Several life-history parameters of northern pike in the upper Niagara River watershed were determined and compared with similar data for other populations of the species. Length-weight characteristics of Niagara River fish were like those of other populations. Ages at sexual maturity corresponded to those for pike from equivalent latitudes. Survival was poor despite rather light exploitation. Growth was similar to that among populations from more northern latitudes.

Many populations of northern pike (*Esox lucius*) have been studied, and the biology of the species is fairly well understood. The Niagara River watershed has a sizable population, but it has not received much attention from researchers. During 1975 and 1976, the authors conducted a study of esocids in the Niagara River to investigate the ecological interactions between northern pike and muskellunge (Harrison, 1978). Their data pertaining to the biology of the local pike population indicated that it supported a low-level fishery. However, according to angler accounts, this fishery was at one time more important in terms of numbers and size of fish caught. Unpublished data collected by the State Conservation Department in the early 1960's suggested that northern pike were once much more numerous in the main body of the river than they were during this study. Therefore, the authors' data are presented here along with some previously published data on other northern pike populations to provide a basis for comparison with both past and future conditions. Such comparison is important in planning effective management.

The Niagara River flows northward from Lake Erie to Lake Ontario and is divided into two nearly equal sections by Niagara Falls. Fourteen major tributaries flow into the 31-kilometer upper section. All are slow, meandering creeks with heavily silted and debris-strewn bottoms. Except for Tonawanda Creek, which is part of the Erie-Barge Canal, depths do

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not exceed 1.5 to 2.0 meters. Water quality in all of the creeks has been degraded by man's development of the surrounding watershed.

METHODS

Eleven tributaries were sampled at least once, but effort was concentrated on three representative creeks and the main body of the river. In 1975 and 1976, 623 northern pike were collected from the study area by trapnets (405), seines (199), electrofishing (13) and other means (6). Sampling of Gun Creek, Woods Creek and Big Six Mile Creek (in 1976 only) produced 315, 223 and 61 northern pike, respectively, but despite extensive effort only 18 were collected from the Niagara River. Total length (in centimeters), weight (in grams) and any external evidence of disease were recorded. When possible, sex was determined by extrusion of milt or roe. Scales were taken from the area just above the left lateral line and below the origin of the dorsal fin. Fish longer than 40 centimeters were marked with orange dart tags inserted immediately below the center of the dorsal fin, while smaller fish were marked with monel strap-tags placed around the anterior rays of the dorsal fin. Each tag carried an individual identifying number and a return address.

Length-weight relationships for fish from the Niagara River system were derived by logarithmic regression of the data for each fish examined. If necessary in analyzing published records, data were converted to the centimeter-gram system, and fork lengths were converted to total lengths according to the factors given by Carlander (1969:336). Relationships for grouped data from other populations were obtained from weighted (by sample size) regression of mean weight against mean length for the length intervals used in each case. For comparisons between length-weight relationships, if either the regression line slopes or the weight-axis intercepts were significantly different at the 95 per cent confidence level, the relationships were considered different. When a difference between two relationships was found, the length coordinate of the intersection of the regression lines was determined algebraically. Individuals from populations with regression line slopes exceeding that of fish from the Niagara watershed were likely to weigh less at lengths shorter than the intersect values and vice versa.

A subsample of 325 fish (including all those of known sex) were aged from dry-mounted scales projected at 40× magnification. For fish captured in early spring, an annulus was assumed at the scale margin. The difficulty of annulus identification increased with the age of the fish, so that one specimen older than 7+ years was eliminated from the analyses. Magnified distances from the focus to each annulus and to the scale margin were measured along the anterior radius of each scale. Logarithmic regression of total length and mean scale length (for three to five scales) provided the body-scale relationship. Back-calculations to deter-

mine the body length at each annulus were made according to the following equation

$$TL_i = 9.29 + (TL - 9.29)\left(\frac{AL_i}{AL}\right)^{1.313}$$

in which

TL_i = body length at each annulus

TL = total length of specimen

AL_i = distance from scale focus to each annulus

AL = distance from scale focus to scale margin

Statistical comparisons of growth were made at the 95 per cent confidence level.

Due to difficulty in determining the age of older fish, the method described by Heincke (1913) was generally used to estimate survival. The ratio of recaptures reported by anglers in 1976 (16) to the number of legal-sized fish (45 centimeters or more in total length) tagged during the 1976 spawning run (252) provided an estimate of exploitation. Fish that grew to legal size after being tagged or that lost their tags, as well as unreported recaptures, were not considered in the estimate.

RESULTS AND DISCUSSION

The data pertaining to the different parameters considered are presented and discussed separately.

LENGTH-WEIGHT

Length-weight data for northern pike in the Niagara River system were separated by sex, month and creek, and the length-weight relationships for these categories were examined. During the spawning season (late February to April), females were significantly heavier than males of comparable length. Although the relationships for successive months did not differ statistically, some trends were evident. Large fish of both sexes were heaviest in February, gradually lost weight as the spawning season progressed and were lightest in summer (May and later). Smaller, presumably immature fish gradually gained weight through the spawning season. The trend in the monthly relationships for Woods Creek fish was similar to that for Gun Creek fish, but weight decline occurred somewhat later in Woods Creek than in Gun Creek. The lag may have reflected a later spawning time in Woods Creek. Because of small sample size, the relationship for fish in Big Six Mile Creek was determined for April only and was similar to

Table 1. Mean Weight According to Total Length For 560 Northern Pike Collected From the Niagara River System During 1975 and 1976.

Total length (centimeters)	Mean weight (grams)	Sample size
18.0 - 20.9	37.4	5
21.0 - 23.9	57.8	6
24.0 - 26.9	83.8	6
27.0 - 29.9	132.8	9
30.0 - 32.9	202.1	19
33.0 - 35.9	250.0	19
36.0 - 38.9	302.4	55
39.0 - 41.9	394.7	76
42.0 - 44.9	484.2	82
45.0 - 47.9	601.0	57
48.0 - 50.9	752.8	40
51.0 - 53.9	930.4	43
54.0 - 56.9	1,129.7	42
57.0 - 59.9	1,337.5	27
60.0 - 62.9	1,617.0	23
63.0 - 65.9	1,722.4	18
66.0 - 68.9	1,803.1	8
69.0 - 71.9	2,485.2	11
72.0 - 74.9	2,664.0	5
75.0 - 77.9	3,232.9	7
78.0 - 80.9	3,492.0	1
81.0 - 83.9	3,311.0	1

the April relationship for Gun Creek fish. No statistical differences in the summer relationships by creek were evident.

Grouped length-weight data for pike from the Niagara River system are presented in Table 1, and the logarithmic relationships are listed by sex and sampling season in Table 2 along with those for other populations. As noted in the preceding paragraph, comparisons are only valid within the given subsets. During the spawning season, the weight of females in Niagara waters did not differ statistically from that of females from Lake Erie or Saskatchewan. Males were significantly lighter than males from Lake Erie, but similar to those from Saskatchewan. In summer, the weight of Niagara fish was comparable to that of the other populations listed except for those in Pennsylvania. Niagara fish shorter than 57 centimeters were lighter than Pennsylvania fish of equivalent length.

Growth

Growth data for the sample from the Niagara River system are presented in Table 3 as weight and length at capture and back-calculated length. Back-calculated lengths showed significant, sexually dimorphic growth from age II on, but no statistical differences in growth from creek to creek were evident. Growth of pike in the Niagara River system is com-

TABLE 2. LENGTH-WEIGHT RELATIONSHIPS FOR NORTHERN PIKE FROM THE NIAGARA RIVER SYSTEM AND OTHER NORTH AMERICAN LOCATIONS.

Location	Sample size	Slope	Intercept	Intersection‡ (centimeters)
Niagara River system				
Male*	201	3.140 ± 0.053†	2.458 ± 0.087†	
Female*	42	3.008 ± 0.171†	2.203 ± 0.300†	
Both sexes (summer)§	130	3.152 ± 0.046†	2.476 ± 0.074†	
Lake Erie (Brown and Clark, 1965)*				
Male	218	2.779	1.799	57.4
Female	279	2.902	1.923	ns
Saskatchewan (Koshinsky, 1972)*				
Male		3.11	2.409	ns
Female		3.11	2.392	ns
Pennsylvania (Buss and Miller, 1961)§	540	2.988	2.188	57.0
Clear Lake, Iowa (Ridenhour, 1957)§	188	3.122	2.430	ns
Michigan (Beckman, 1945)§	1,153	3.066	2.347	ns
Mackenzie River drainage (Miller and Kennedy, 1948)§	281	3.17	?	ns

*Data taken during spawning season.

§Data taken outside spawning season.

†Variability represents standard error.

‡ns represents no significant difference in either slope or intercept.

Table 3. Weight and Length At Time of Capture, and Back-calculated Length, According to Sex and Age For Northern Pike From the Niagara River System*

Sex§	Age						
	I+	II+	III+	IV+	V+	VI+	VII+
	Weight (grams)						
Sample	166 (46)	417 (137)	800 (58)	1,388 (42)	2,268 (12)	2,699 (4)	3,600 (1)
Male	143 (9)	420 (107)	740 (39)	1,101 (20)	1,969 (5)	1,814 (1)	
Female	(0)	482 (13)	1,017 (14)	1,699 (16)	2,593 (5)	2,994 (3)	3,600 (1)
	Total length (centimeters)						
Sample	28.7 (60)	41.2 (142)	50.2 (62)	59.1 (43)	69.6 (12)	72.8 (4)	75.6 (1)
Male	28.8 (9)	41.3 (110)	49.3 (42)	55.6 (21)	67.0 (5)	66.5 (1)	
Female	(0)	43.3 (13)	53.9 (14)	63.7 (16)	73.6 (5)	74.9 (3)	75.6 (1)
	Back-calculated length (centimeters)						
Sample	25.1 (324)	38.8 (264)	49.3 (122)	58.5 (60)	66.7 (17)	71.6 (5)	75.6 (1)
Male	25.3 (188)	38.4 (179)	47.7 (69)	55.5 (27)	63.6 (6)	65.2 (1)	
Female	25.3 (52)	40.8 (52)	52.3 (39)	61.8 (25)	69.4 (9)	73.2 (4)	75.6 (1)

*Figures in parentheses represent the number of fish in each category.

§"Sample" represents the total known males, known females and fish of undetermined sex.

TABLE 4. TOTAL LENGTH (IN CENTIMETERS) ACCORDING TO SEX AND AGE FOR NORTHERN PIKE FROM THE NIAGARA RIVER SYSTEM AND OTHER NORTH AMERICAN WATERS,

Location	Sample size	Age						
		I	II	III	IV	V	VI	VII
	Male							
Niagara River system§	188	25.3	38.4	47.7	55.5	63.6	65.2	. .
East Harbor (Lake Erie), Ohio†	289	30.5	43.7	50.3	55.4	58.9	61.2	64.3
Murphy Flowage, northern Wisconsin‡	?	43.2	52.1	56.9	63.5	. .	. .	. .
Thomas Creek (tributary of Lac la Ronge), Saskatchewan§§	?	. .	40.1	51.9	59.0	63.6	67.1	69.8
Kinosao Creek (tributary of Lac la Ronge), Saskatchewan§§	?	. .	41.2	48.8	54.2	58.4	61.7	64.9
Mackenzie River drainage, Canada††	?	10.7	16.5	23.8	31.6	36.5	44.4	50.1
	Female							
Niagara River system§	52	25.3	40.8	52.3	61.8	69.4	73.2	75.6
East Harbor (Lake Erie), Ohio†	399	28.7	45.7	55.4	62.0	67.8	69.6	75.7
Murphy Flowage, northern Wisconsin‡	?	44.2	55.1	62.0	68.8	. .	. .	. .
Thomas Creek (tributary of Lac la Ronge), Saskatchewan§§	?	. .	40.1	53.0	64.4	72.0	76.8	80.9
Kinosao Creek (tributary of Lac la Ronge), Saskatchewan§§	?	. .	42.8	52.5	59.5	64.9	69.8	74.1
Mackenzie River drainage, Canada††	?	10.7	16.3	23.6	30.8	37.8	44.7	50.9
	Sample*							
Niagara River system§	324	25.1	38.8	49.3	58.5	66.7	71.6	75.6
Lake Erie, Pennsylvania‡‡	130	30.0	48.5	60.7	70.4	79.0	. .	. .
All Waters, Pennsylvania‡‡	482	27.2	48.5	58.9	67.1	74.7	86.1	. .
Lake Mendota, southern Wisconsin#	64	29.0	54.1	67.8	76.7	86.1	92.5	96.3
Delta Lake, northern Wisconsin#	39	21.1	39.9	50.0	57.9	63.0	66.8	73.2

*"Sample" represents the total known males, known females and fish of undetermined sex.

§Present study; data derived by back-calculation.

†Clark and Steinbach (1959); data derived by back-calculation from linear body-scale relationship with zero intercept.

‡Threinen et al. (1966); derivation of data unknown.

§§Koshinsky (1972); believed to be measured data taken near time of annulus formation. Fork length converted to total length by factor given by Carlander (1969).

††Miller and Kennedy (1948); data derived by curvilinear back-calculation.

‡‡Buss and Miller (1961); data derived by back-calculation. "All waters" represents statewide average.

#Van Engle (1940); derivation of data unknown.

pared with that of other populations in Table 4. These data showed a tendency for growth to have been more rapid in southern latitudes, but the many exceptions suggest that other factors are also important. In general growth in Niagara waters was relatively slow and resembled that of fish from higher latitudes such as northern Wisconsin and Saskatchewan.

Age at Sexual Maturity

The age-frequency distributions given in Table 3 suggest that male pike matured during their second year, although a few precocious 1-year-old males were encountered. Age at maturity for females was less clearly defined. Several mature 2-year-old and 3-year-old females were taken. However, considering year-to-year survival, it appeared that most females matured in their fourth year. In Wisconsin, studies by Threinen et al. (1966) indicated that most males had matured by age II, and most females by age III. Williamson (1942) gave the age at maturity in Wisconsin waters as age II, but he did not differentiate by sex. In Saskatchewan, some female fish were mature by age III, but most males were not mature until age IV (Rawson, 1932). Miller and Kennedy (1948) found that northern pike in more northern latitudes (such as Great Bear Lake) mature much later, i.e., males during their fifth summer and females during their sixth summer. In general, the age at maturity of pike in the Niagara River watershed corresponded to that of populations from similar latitudes.

Sex Ratio

The sex ratio of the present sample was 3.56:1 (228 males to 64 females). This ratio was similar to that (3.00:1) found by Hiner (1961) during spawning runs in North Dakota, but it was more unbalanced than ratios given in much of the literature. Franklin and Smith (1963) gave a sex ratio of 2.03:1 for spawning northern pike in Lake George, Minnesota, while Clark and Steinbach (1959) reported a ratio of 0.72:1 for Lake Erie fish captured in March. Carbine (1941) found sex ratios of 1.88:1 and 1.36:1 in two successive years among spawning northern pike in Houghton Lake in Michigan. Several factors (e.g., sex-dependent behavior patterns) may produce errors in estimating sex ratios. The sex ratio reported for the present study may have been biased toward males by the longer time during which males are sexable by the extrusion method. Difference in age at maturity may also be a factor. For example, if only age IV and older fish from the Niagara watershed are considered, the estimated ratio would be 1.12:1 (28 males to 25 females). Therefore, accurate determination of the sex ratio for the population as a whole is difficult, and only general comparisons among populations are possible.

SURVIVAL AND EXPLOITATION

The subsample used for age determination consisted mainly of sexually mature fish, so ages I to III are not properly represented in the age-frequency distributions. Therefore, survival estimates from data for the Niagara River watershed were applicable only to age IV or older fish. From these data, annual survival was estimated by Heincke's method as 25 per cent for males, 36 per cent for females and 30 per cent for both sexes combined. Estimated by the catch-curve method, survival was 31 per cent for both sexes combined. When Heincke's method was applied to data for Lake Erie as given by Clark and Steinbach (1959), estimated survival rates of 59 per cent and 65 per cent were indicated for age IV and older males and females, respectively. Similarly, a survival of 39 per cent was estimated for northern pike (sexes combined) in Ball Club Lake in Minnesota from data given by Johnson (1956). Variations in year-class strength may have caused errors in these estimates, but survival in Niagara waters seems to have been near the lower end of the range for the species.

The rate of exploitation was estimated as 6.3 per cent, but this may have been an underestimate due to tag loss and unreported recaptures.

PARASITES

All captured northern pike were examined for external evidence of parasitism, disease or injury. There was no evidence of lymphosarcoma or of "red-sore" disease, and only four individuals showed evidence of lamprey attack. Although mortality due to injury by lampreys could not be measured, the rarity of scarring suggests that lampreys did not have a significant impact on the population. Of the pike collected, 22 per cent had black-spot disease (Harrison and Hadley, 1982). The incidence of infection was inversely related to size and age, and males were more frequently infected than females. Diseased fish grew more slowly than uninfected fish, but cause and effect relationships were not clear. The length-weight relationship for diseased fish was not statistically different from that for uninfected fish.

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RETENTION OF BLACK SEA BASS IN VENTED AND UNVENTED LOBSTER TRAPS[1]

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ABSTRACT

Field collections showed no significant differences in the numbers and mean total lengths of black sea bass retained by vented vs. unvented lobster traps. While linear regression analysis of morphometric characters of black sea bass indicated that traps equipped with 58-millimeter escape vents would not retain fish less than 210 millimeters in total length, in practice both vented and unvented traps retained equal proportions of such small bass. Analysis of the lobster catch agreed with other studies that traps equipped with escape vents took fewer sub-legal lobsters while catching more legal-sized lobsters.

The Northeast Marine Fisheries Board's recent comprehensive management plan (Northeast Marine Fisheries Board, 1978) for the American lobster (*Homarus americanus*) includes a recommendation that would require the use of escape vents on all lobster traps. The beneficial effects of such vents with respect to the catch of legal and sub-legal lobsters have already been well documented (Krouse and Thomas, 1975; Krouse, 1978; Fair and Estrella, 1976; Nulk, 1978; Fogarty and Borden, 1980). These studies have shown that escape vents substantially reduce the numbers of sub-legal lobsters retained in traps, thereby minimizing injuries and mortality due to handling and gear-related damage. In addition, the use of escape vents often significantly increases the catch of legal-sized lobsters. Although vented traps would obviously be desirable for reducing mortality among sub-legal lobsters, the effects of escape vents on the catch of other species incidental to the lobster fishery are not well known. Studies in Maine (Krouse, 1978) showed that circular vents will retain harvestable-sized rock crabs (*Cancer irroratus*) and jonah crabs (*Cancer borealis*), but their effect on the incidental catch of fish species was not reported.

Briggs and Mushacke (1980), in their survey of the inshore pot fishery off the south shore of Long Island, noted that, of the finfish caught, only the black sea bass (*Centropristis striata*) was then of economic importance. In recent years, the commercial landings of black sea bass in New York State have been on the increase (Anonymous, 1972-1980; Fred Blossom, Natl. Marine Fish. Serv., personal communication), and it is estimated that half of these landings can be attributed to the lobster pot fishery (Briggs and

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Mushacke, 1980). Since black sea bass comprise an important part of this fishery, there is a need for information concerning the possible effect of escape vents on the catch and market value of this species. The present study was undertaken with the following objectives: (1) to compare the sizes, numbers and weights of black sea bass retained by vented and unvented lobster traps; and (2) to compare the actual minimum size of black sea bass retained by vented traps with a theoretical minimum based on analysis of body measurements.

METHODS

Data on the number, weight and size composition of the catch were collected during 24 trips aboard a commercial lobster vessel fishing off the south shore of Long Island between May 6 and November 30 in 1980. Escape vents (plastic panels with two circular openings 58 millimeters in

Figure 1. Examples of unvented (left) and vented (right) lobster traps used during study.

diameter, purchased from the Plante Manufacturing Co.[2] in Maine) were installed at the base of the parlour area on half of the 120 lobster traps used for the study. The traps were half-round and constructed of nylon mesh and wood (Figure 1), the type commonly used in the study area.

[2]The use of a commercial product implies neither endorsement nor rejection of the product by the New York State Department of Environmental Conservation.

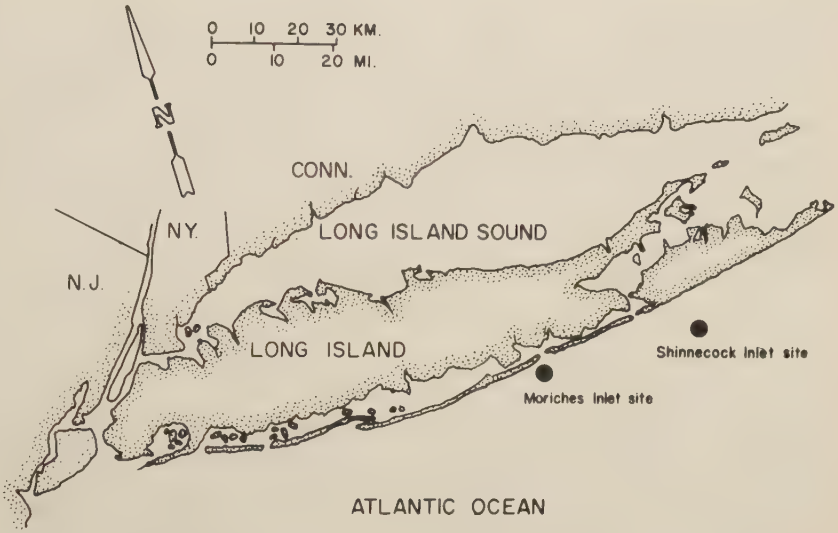

Figure 2. Map of Long Island showing collection sites.

They were placed on five strings, alternating vented and unvented traps. The strings were set in 20 to 40 meters of water at two locations. From May 6 to August 13, all five strings were set 3.25 kilometers due south of Moriches Inlet. Subsequently, they were moved to an area approximately 11 kilometers southeast of Shinnecock Inlet (Figure 2).

All black sea bass taken in each vented and in each unvented trap were counted. In addition, beginning with the second string hauled on June 6, the total length of each bass was measured to the nearest millimeter and the weight of each string in pounds was recorded. Throughout the study, the numbers of legal and sub-legal lobsters, as well as berried females, were also recorded for each trap. No data are available for July because trapping was suspended due to fire damage aboard the contractor's vessel.

Field data on the catch of black sea bass by vented and unvented traps were compared by analyzing differences in length frequencies, catch per trap haul, and total poundage. Total weights were analyzed from data for June through November only. Additional data on legal and sub-legal lobsters were analyzed by catch per trap haul. The number of days the traps were set versus the catch were not analyzed due to the limited number of trips and the high variability in the duration of trapping per trip.

Sampling for total length, body depth and body width to determine the theoretical size of black sea bass that could pass through the escape vent was done at various local fish-packing facilities. A theoretical size for bass that would be retained was calculated by linear regression from the body measurements obtained.

Table 1. Summary of Catch Retained By Vented and Unvented Lobster Traps Off the South Shore of Long Island in 1980.

Trip No.	Duration of trapping* (days)	Vented traps				Unvented traps			
			Catch				Catch		
				Lobster				Lobster	
		Trap hauls	Black sea bass	Legal-sized§	Sub-legal	Trap hauls	Black sea bass	Legal-sized§	Sub-legal
1	16	60	3	6 (1)	2	60	1	4 (2)	5
2	9	60	17	3 (1)	2	60	14	10 (4)	1
3	5	55	49	4	1	56	34	13 (3)	1
4	17	55	135	47 (19)	4	55	112	31 (13)	9
5	5	55	55	35 (10)	7	54	57	21 (3)	9
6	9	55	53	32 (8)	3	53	33	32 (3)	5
7	42	52	16	110 (2)	7	51	9	59	11
8	5	52	5	9	2	51	1	17	5
9	7	52	1	11	7	52	1	14	3
10	5	53	0	7	4	50	0	5	4
11	10	29	1	28 (7)	6	27	1	11 (4)	10
12	8	53	2	51 (15)	6	50	3	45 (17)	25
13	10	52	0	38 (5)	7	50	1	23 (1)	12
14	3	53	0	7 (11)	4	50	0	6 (3)	2
15	8	32	0	23 (9)	1	30	0	23 (11)	3
16	4	52	8	20 (8)	3	50	11	19 (9)	14
17	3	52	26	2 (1)	0	50	26	3 (1)	0
18	3	50	63	1 (1)	1	50	59	1	0
19	3	51	31	0	0	50	32	1	2
20	5	51	26	6 (1)	0	49	36	2 (1)	2
21	3	51	31	0	1	49	43	1 (1)	4
22	3	50	59	0	0	49	46	2 (2)	0
23	8	26	1	2 (2)	0	20	1	0	0
24	9	25	5	2 (1)	0	22	3	1 (1)	1
Total	200	1,176	587	444 (102)	68	1,138	524	344 (79)	128

*Time between date traps were first set into the water and date on which they were retrieved and emptied, i.e., "set over days".

§Comprises all lobsters 81 millimeters or more in carapace length, including berried females the numbers of which are shown in parentheses.

RESULTS

During the study, 2,314 trap hauls were made, and 1,111 black sea bass and 984 lobsters were caught and measured. A sample of 223 black sea bass from three local fish-packing facilities were measured for total length, body depth and body width. The results are presented according to the two principal objectives, and additional data concerning the lobster catch are included.

COMPARATIVE RETENTION OF BLACK SEA BASS BY VENTED AND UNVENTED TRAPS

The total catch retained by vented and unvented traps is summarized in Table 1. The monthly catch of black sea bass per trap haul (Figure 3) closely followed the seasonal pattern as previously reported by Kendall (1977), Musick and Mercer (1977) and Briggs and Mushacke (1980). The results showed that the seasonal variations for both vented and unvented traps were virtually identical, with the highest catch rates occurring in June followed by a sharp decline during August and September. A second, smaller peak was obvious for both types of traps in October, as was a final decline in November as the fish moved southward toward their offshore wintering grounds.

Of the 1,111 black sea bass caught, 587 were retained by the vented traps while 524 were retained by the unvented traps. Chi-square analysis of the catch data showed no significant difference ($P > 0.01$) in the numbers retained by the two types of traps.

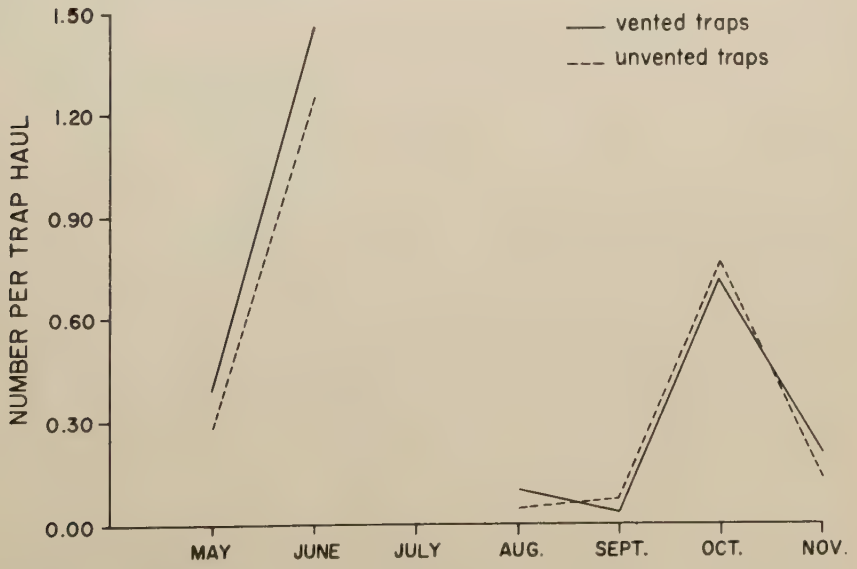

Figure 3. Monthly catch of black sea bass per trap haul.

The length-frequency distribution for black sea bass from vented and unvented traps is shown in Figure 4. Bass from vented traps ranged from 171 to 609 millimeters in total length and averaged 310.2 millimeters, while those from unvented traps ranged from 187 to 619 millimeters and averaged 319.9 millimeters. The means were subjected to a t-test and found to be not significantly different at the 0.05 level of probability (t = 1.5035). The largest proportion retained was in the 226 to 250-millimeter size range, which is equivalent to age III fish according to calculations by

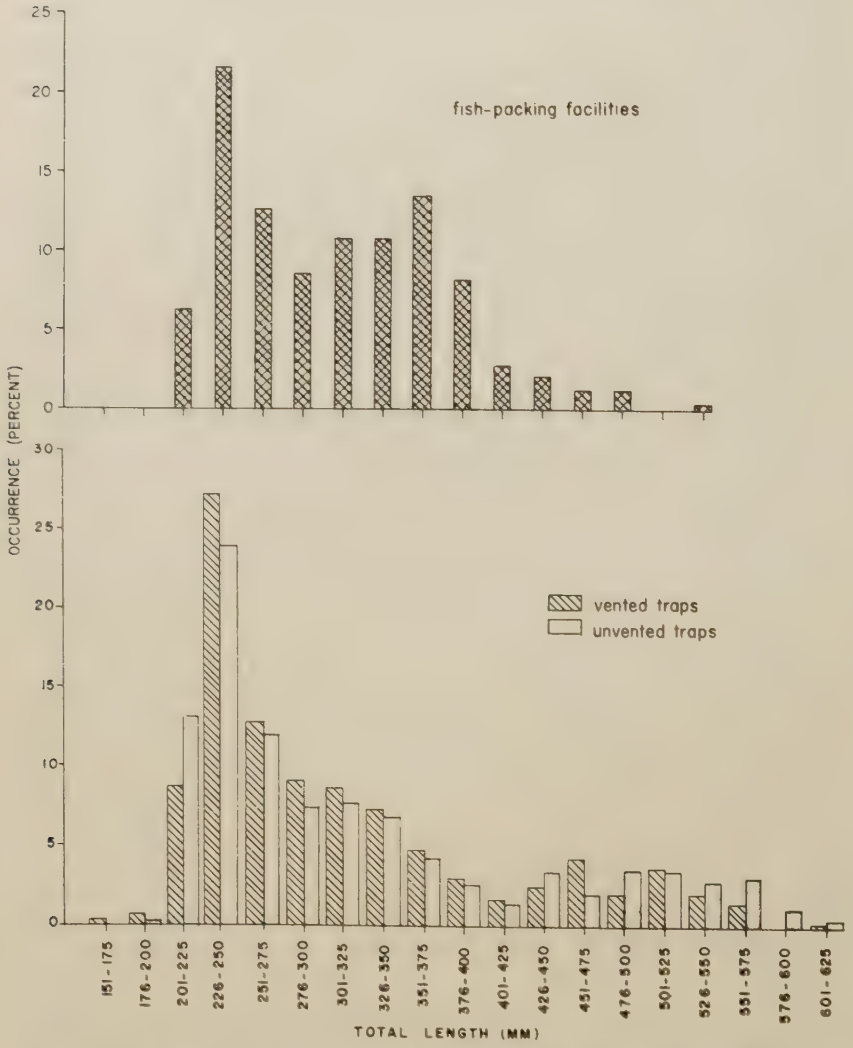

Figure 4. Length-frequency distribution of black sea bass taken in vented (498) and unvented (459) traps from June 6 to November 6 compared with that of 233 specimens measured at local fish-packing facilities.

Briggs (1978). Less than 1 per cent of those caught were under 203 millimeters long (the legal commercial size limit in New York State). Only seven sub-legal bass were retained, of which five were found in vented traps and two in unvented traps, too few to indicate meaningful differences.

In the 1,939 trap hauls for which weights were recorded, the catch of black sea bass was 957 with a total weight of 572.4 kilograms (1,262 pounds), or an average of 598 grams. The average market value (ex-vessel) for black sea bass ranged from \$0.92 per pound in June to \$1.77 per pound in September (Fred Blossom, Natl. Marine Fish. Serv., personal communication). The vented traps caught 620 pounds of bass worth \$665.00, while the unvented traps caught 642 pounds worth \$703.00. The average for the bass retained by both types of traps was \$1.08 per pound.

THEORETICAL SIZE OF BLACK SEA BASS RETAINED BY VENTED TRAPS

The 223 black sea bass examined at packing houses ranged from 209 to 521 millimeters in total length and averaged 309.2 millimeters. The largest proportion were in the 226 to 250-millimeter size range. Length-frequency analysis of these data (Figure 4) showed a size distribution similar to that for the specimens taken in the traps hauled. Comparison of the bass retained by the vented and unvented traps with those measured at the packing houses showed no significant difference in total length among the three groups ($P > 0.01$).

Linear-regression analyses of the body measurements are shown graphically in Figures 5 and 6. The resultant equation for the relationship of total length to body depth is

$$Y = 1.49 + 0.27X$$

where

Y = body depth in millimeters
X = total length in millimeters

The correlation coefficient ($r = 0.9325$) indicated a close relationship between the two variables. According to this equation, the smallest size for black sea bass that would be expected to be retained in a lobster trap with a 58-millimeter circular vent would be 210 millimeters in total length. Contrary to this, the actual field data showed that, for both vented and unvented traps, 2.6 per cent of the bass retained were shorter than that, indicating no apparent difference in the selectivity of the two types for small fish.

LOBSTER DATA

A total of 984 lobsters were caught in the 2,314 trap hauls. Of these, 196 were of sub-legal size (less than 81 millimeters in carapace length) and 181

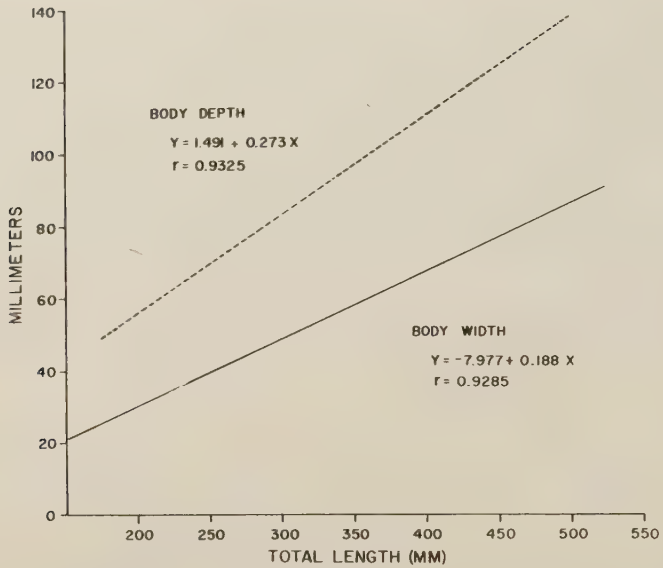

Figure 5. Relationship of body depth (dash line) and body width (solid line) to total length for black sea bass.

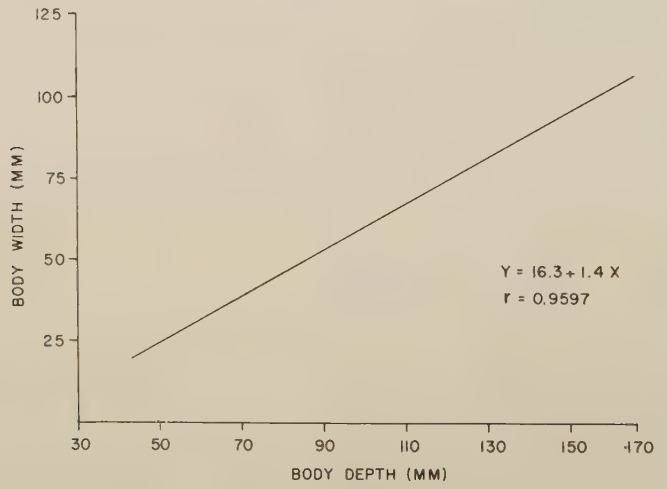

Figure 6. Relationship of body width to body depth for black sea bass.

were berried females. Table 2 shows the monthly catch of sub-legal, legal-sized and berried female lobsters for the vented and unvented traps. The catch per trap haul is depicted graphically in Figure 7. The highest rates of catch occurred from June through September. Chi-square analysis showed that the catch of legal-sized lobsters per trap haul was significantly higher ($P < 0.005$) for vented than for unvented traps, indicating that the vented

TABLE 2. MONTHLY CATCH OF LOBSTERS IN VENTED AND UNVENTED TRAPS OFF THE SOUTH SHORE OF LONG ISLAND IN 1980.

Size of lobsters and number of trap hauls	May	June	July	August	September	October	November	Total
				Vented traps				
Legal*	13 (2)	114 (37)	§	165 (9)	139 (48)	11 (5)	2 (1)	444 (102)
Sub-legal	5	14	§	26	21	2	0	68
Total	18	128	§	191	160	13	2	512
Trap hauls	175	165	§	238	242	331	25	1,176
				Unvented traps				
Legal*	27 (9)	84 (19)	§	106 (4)	116 (41)	10 (5)	1 (1)	344 (79)
Sub-legal	7	23	§	33	56	8	1	128
Total	34	107	§	139	172	18	2	472
Trap hauls	176	162	§	231	230	317	2	1,138

*Comprises all lobsters 81 millimeters or more in carapace length, including berried females the numbers of which are shown in parentheses.
§Data lost (see text).

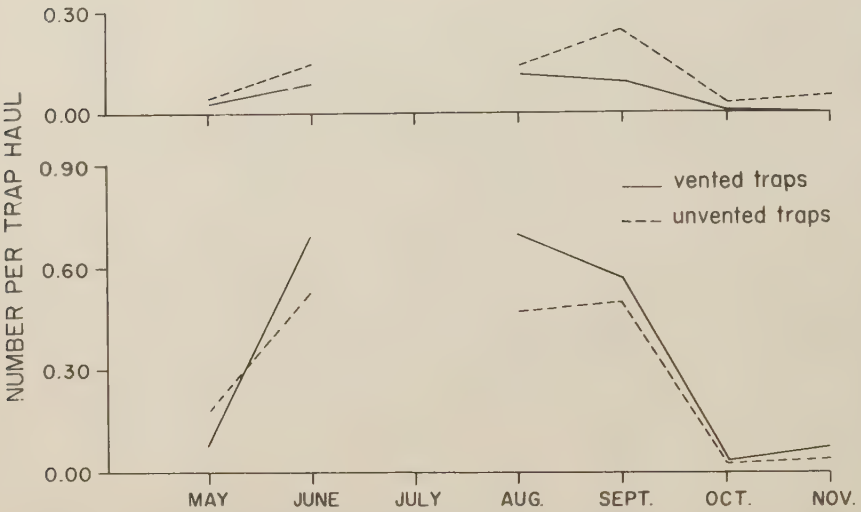

Figure 7. Monthly catch of legal-sized lobsters (below) and sub-legal lobsters (above) for vented and unvented traps.

traps were more likely to contain legal-sized lobsters than the unvented traps. Similarly, the catch of sub-legal lobsters per trap haul was significantly lower ($P < 0.005$) for vented than unvented traps, showing that the escape vents were effective in allowing the release of sub-legal lobsters.

DISCUSSION

Calculations based on linear-regression analysis of data for total length and body depth indicated that lobster traps equipped with 58-millimeter escape vents should retain all black sea bass more than 210 millimeters long. However, actual field collections showed no significant differences in the numbers and lengths of bass retained in vented versus unvented traps. Furthermore, some 3 per cent of the bass retained by both types of traps were equal to or smaller than this theoretical retention size. From these data, the estimated loss of black sea bass and its associated market value as a result of the use of escape vents would be negligible.

Although differences in the catch rates of black sea bass were negligible, there were significant differences in the retention of lobsters by the vented and unvented traps. The data confirm previous reports that traps equipped with escape vents take fewer sub-legal lobsters and more legal-sized lobsters than traps without vents. Therefore, it is concluded that the use of escape vents is not only an effective means of reducing mortality among sub-legal lobsters, but it is also an efficient method of harvesting legal-sized lobsters without an appreciable loss of black sea bass.

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THE BLACK LAKE FISH COMMUNITY: 1931 to 1979

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ABSTRACT

Significant changes in the fish community in Black Lake have taken place since 1931, the most important being the decline of the walleye population following the establishment of the black crappie in the late 1950's. During the 1970's the fish community was dominated by panfish, primarily black crappie, yellow perch and pumpkinseeds. Data collected from 1975 to 1979 suggest that the dynamics of this community have been strongly influenced by dominant year classes of the black crappie which apparently suppressed recruitment of its own young along with those of associated species. A period of unstable walleye recruitment in the late 1960's may have allowed the black crappie to produce large year classes. Competition for forage fish from these large year classes may have increased the vulnerability of adult walleyes to being taken by angling. Coupled with crappie predation on walleye fry, this may have eventually reduced stocks below viable levels. Other changes in species composition and growth rates are discussed.

Black Lake (Figure 1), in St. Lawrence County in northern New York, lies within the Indian River Lakes region as defined by Will et al. (1982). It is a shallow, productive lake with an area of 3,350 hectares and an average depth of 3 meters (maximum 5 meters). During the past 50 years, significant changes in the fish community have taken place, the most important being the loss of walleyes and the establishment of a large black crappie population.

The State Conservation Department's fishery survey in 1931 indicated that the lake supported a diverse fish community with the walleye being the dominant predator (Odell, 1932). Fish management surveys by the Department in 1950 and 1963 provided similar results. Based on intensive sampling from 1975 to 1979, it was apparent that the walleye population had declined to remnant levels and that the black crappie had become the most abundant species present.

Due to its importance to the sport fishery, the walleye population has been studied intensively. A tagging study in 1953 was followed by a more detailed investigation from 1961 to 1964 designed to provide information on growth rates, population size, spawning success and angler harvest. The age structure among spawning males (LeTendre and Schneider, 1969) indicated that recruitment was stable during the latter period. From 1969 to 1973, Forney (1975) evaluated the contribution of stocked walleye fry to the total fry population. Fry were stocked in alternate years, but densities were low both in years when stocking was done and in years when it was not done. Data gathered in 1975 on the age structure among spawning males, the abundance of walleye fingerlings and the relative abundance of adult walleyes indicated that the population had declined to a remnant level (Schiavone, 1981). The decline apparently began with the production of

Figure 1. Map of Black Lake showing depths (in feet).

weak year classes in the late 1960's followed by year-class failures from 1970 to 1975.

While there has been speculation that the introduction and establishment of the black crappie was a major factor in the decline of the walleye, other changes in the fish community, habitat and angler use have not been

evaluated. The present paper describes changes in the fish community and aquatic environment from 1931 to 1979, documents the structure and dynamics of the fish community from 1975 to 1979 and discusses factors which may have led to the walleye decline.

MATERIALS AND METHODS

In addition to published reports, files of the State Department of Environmental Conservation were reviewed for historical information. Scales from specimens of yellow perch and pumpkinseed collected in 1931 and stored at the New York State Museum in Albany were obtained to evaluate growth at that time.

Information on the current status of the fish community was recorded in 1975, 1978 and 1979. Samples were collected with a 5.9-meter otter trawl at five sites by 5-minute tows along the bottom at an approximate speed of 5 kilometers per hour. These collections were made once a month from May through October in 1975, from May through September in 1978 and during June in 1979.

In 1975 and 1978, gillnet collections were made from May through September at locations representing a variety of habitat types, including rocky shoals, shallow weedy areas and muck bottom. There were 14 collections in 1975 and 12 in 1978. The nets used were 46 meters long and 1.8 meters deep, with six 7.7-meter panels of different mesh size, i.e., 13, 19, 25, 32, 38 and 45 millimeters (bar measure). Three nets were generally set overnight perpendicular to shore with the small mesh inshore.

When possible, total-length measurements were recorded for yearling and older fish and a representative subsample of fingerlings (age 0) collected each sampling day. Scale samples were taken from a representative subsample of each species collected. Scale impressions were made on cellulose acetate slides and examined with a binocular microscope to determine age. The relative abundance of different age groups was estimated from the age and length-frequency distributions, using procedures described by Ketchen (1949).

To augment northern pike collections, three cooperating marina operators provided total-length measurements and scale samples from 112 pike caught by anglers during May and early June in 1978. Also, 31 largemouth bass and 17 smallmouth bass were collected with a 240-volt electrofishing boat during June 1979.

CHANGES IN COMMUNITY STRUCTURE AND WATER QUALITY: 1931-1979

Fish collections were made in Black Lake during June in 1931, 1950 and 1961 (New York State Conservation Department, unpublished), as well as in 1975, 1978 and 1979. Sampling gear and effort varied and included collections with trapnets, gillnets, seines and trawls (Table 1). While it is not

TABLE 1. SAMPLING GEAR AND EFFORT FOR FISH COLLECTIONS IN BLACK LAKE DURING JUNE OVER PERIOD FROM 1931 TO 1978.

Year	Gear	Effort
1931*	Seine (unspecified)	11 collections
	Trapnet	13 nights
	Gillnet (unspecified)	5 nights
1950*	Trapnet	5 nights
	Gillnet: 30 meters long, various mesh sizes from 25 to 64 millimeters (bar measure)	16 nights
1961*	Trapnet (8)	unspecified
1975§	Gillnet: see text	3 nights
	Trawl: see text	5 tows, 5 minutes each
1978§	Gillnet: see text	3 nights
	Trawl: see text	5 tows, 5 minutes each
1979§	Trawl	5 tows, 5 minutes each
	Electrofishing boat	1 night, shocking time 90 minutes

*Unpublished records of State Conservation Department.
§Present study.

possible to compare catch per unit of effort between these years, it is assumed that the collections provided a reasonable indication of the species present in each sample year, permitting recognition of gross changes in community structure.

The relative abundance of the species collected is summarized in Table 2. In addition to the obvious decline of walleyes and the increase in black crappie abundance, the data also suggest a decline in the abundance of bluegills, rock bass and white suckers. The initially less abundant populations of bowfin, mooneye and redhorse sucker had also declined. The fluctuations in relative abundance of yellow perch and pumpkinseeds were likely related to the selectivity of the various sampling methods. Too few northern pike, largemouth bass and smallmouth bass were collected for changes to be recognized.

Black crappies were not present in 1931 or 1950, but they were abundant in the 1961 trapnet collections. While walleyes were abundant in 1961, only two were collected in 1975 and none in 1978. Based on reports from local anglers and conservation officers, crappies were first introduced from the nearby St. Lawrence River population in the late 1950's by sportsmen.

Data from earlier years that could be used to evaluate changes in growth rates were available only for northern pike, largemouth bass, smallmouth bass, yellow perch and pumpkinseed. They were compared with data for 1975, 1978 or 1979 whichever had the best representation of age groups (Table 3). The differences in mean length between 1931 and 1975 for yellow perch at ages 1, 2 and 4 were significant (t test: $P = 0.05$) indicating more rapid growth in the 1970's. Northern pike, which typically ex-

Table 2. Relative Abundance of Species in the Black Lake Fish Community As Indicated By Collections During June Over the Period From 1931 to 1978*

Species	1931		1950		1961		1975		1978	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Walleye (*Stizostedion v. vitreum*)	38	4.2	54	14.9	42	2.5	2	0.5	0	. .
Northern pike (*Esox lucius*)	20	2.2	24	6.6	5	0.3	1	0.3	5	0.6
Smallmouth bass (*Micropterus dolomeiu*)	0	. .	16	4.4	26	1.5	3	0.8	12	1.3
Largemouth bass (*Micropterus salmoides*)	20	2.2	8	2.2	0	. .	3	0.8	3	0.3
Black crappie (*Pomoxis nigromaculatus*)	0	. .	0	. .	353	21.0	14	3.6	147	16.1
Yellow perch (*Perca flavescens*)	450	49.6	38	10.5	57	3.4	80	20.7	544	59.6
Bluegill (*Lepomis machrochirus*)	24	2.6	78	21.5	563	33.5	7	1.8	8	0.9
Pumpkinseed (*Lepomis gibbosus*)	145	16.0	63	17.4	481	28.6	254	65.8	173	19.0
Rock bass (*Ambloplites rupestris*)	126	13.9	14	3.9	19	1.1	0	. .	2	0.2
Brown bullhead (*Ictalurus nebulosus*)	30	3.3	23	6.3	131	7.8	14	3.6	15	1.6
Yellow bullhead (*Ictalurus natalis*)	1	0.1	0	. .	0	. .	0	. .	0	. .
Channel catfish (*Ictalurus punctatus*)	1	0.1	7	1.9	0	. .	7	1.8	1	0.1
White sucker (*Catostomus commersoni*)	47	5.2	6	1.6	0	. .	0	. .	0	. .
Longnose gar (*Lepisosteus occeus*)	3	0.3	28	7.7	0	. .	1	0.3	3	0.3
Bowfin (*Amia calva*)	0	. .	4	1.1	0	. .	0	. .	0	. .
Mooneye (*Hiodon torgisus*)	2	0.2	0	. .	0	. .	0	. .	0	. .
Redhorse (*Moxostoma* sp.)	1	0.1	0	. .	4	0.3	0	. .	0	. .
Total	908	100.0	363	100.0	1,681	100.0	386	100.0	913	100.0

*Data for 1979 omitted because too few to be comparable.

TABLE 3. COMPARISON OF GROWTH RATES IN 1950 AND EARLIER WITH THOSE IN THE 1970'S FOR FIVE SPECIES IN BLACK LAKE AS INDICATED BY COLLECTIONS DURING JUNE

Species	Year	Mean total length (millimeters) according to age (years)							
		1	2	3	4	5	6	7	8
Yellow perch	1931*	81	111	134	162	. .	. .	. .	. .
	1975	99	144	166	177	. .	. .	. .	. .
Pumpkinseed	1931*	52	87	. .	144	. .	. .	. .	. .
	1975	56	109	130	150	162	171	175	. .
Largemouth bass	1950*	. .	244	. .	. .	. .	399	. .	419
	1979	140	220	. .	330	366	385	. .	. .
Smallmouth bass	1950*	107	206	241	. .	320	310	381	. .
	1979	. .	196	229	274	. .	. .	. .	. .
Northern pike	1950*	307	432	505	536	. .	. .	. .	. .
	1978	. .	511	590	614	658	714	687	894

*Unpublished records of State Conservation Department.

hibit sexually dimorphic growth rates, appear to have grown significantly faster in 1978 than in 1950, but the difference may be misleading since the data for males and females in each age group were combined in determining mean length. It also appears that in the 1970's pumpkinseeds grew faster, and largemouth bass and smallmouth bass slower, than they did in 1931 and 1950, respectively.

Based on sampling in 1931 and 1972, no significant changes in water quality occurred. Faigenbaum (1932) reported a mean total alkalinity (ugl^{-1} $CaCO_3$) of 51 and a pH of 7.7 for Black Lake during June 1931. Mean secchi-disc transparency during the same period was 1.7 meters (Burkholder and Tressler, 1932). During the summer of 1972, the corresponding values were 56, 7.6 and 1.8, respectively, (U.S. Environmental Protection Agency, 1972). Similar values were recorded during the present study in 1975 and 1978.

COMMUNITY STRUCTURE AND DYNAMICS: 1975-1979

The composition of the gillnet and trawl collections in 1975 and 1978 is summarized in Table 4. The gillnet catch indicated that the abundance of most species was similar in both years, although no walleyes and considerably fewer channel catfish were taken in 1978. On the other hand, black crappies increased from about 3 to 9 per cent in the gillnet catch, and this was reflected in an increase from about 15 to 40 per cent for yearlings and older fish in the trawl catch. Although pumpkinseeds did not show a decline in the gillnet catches, they dropped from about 46 to 19 per cent in the trawl catches.

The composition of the catch of young-of-the-year fish in the trawl collections in 1975 and 1978 is given by month in Table 5 for the more abundant species. Yellow perch and black crappie were the only species repre-

Table 4. Number and Proportion of the Catch For Species Taken in Gillnet and Trawl Collections in Black Lake in 1975 and 1978*

Species	Gillnet				Trawl§			
	1975		1978		1975		1978	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Walleye	15	1.1	0	. .	0	. .	0	. .
Northern pike	12	0.8	21	1.6	0	. .	2	0.1
Largemouth bass	6	0.4	8	0.6	2	0.3	2	0.1
Smallmouth bass	10	0.7	22	1.7	0	. .	1	0.1
Yellow perch	676	47.6	515	40.6	238	35.5	811	39.2
Black crappie	39	2.7	114	9.0	100	14.9	833	40.3
Pumpkinseed	401	28.3	409	32.3	312	46.5	387	18.7
Bluegill	21	1.5	34	2.7	6	0.9	0	. .
Rock bass	23	1.6	11	0.9	0	. .	0	. .
Brown bullhead	125	8.8	105	8.3	13	1.9	31	1.5
Yellow bullhead	0	. .	5	0.4	0	. .	0	. .
Channel catfish	82	5.8	5	0.4	0	. .	0	. .
Longnose gar	7	0.5	5	0.4	0	. .	0	. .
White sucker	1	0.1	13	1.0	0	. .	0	. .
Bowfin	1	0.1	2	0.1	0	. .	0	. .
Total	1,419	100.0	1,267	100.0	671	100.0	2.067	100.0
Collections	14		12		6		5	

*Data for 1979 omitted because too few to be comparable.
§Includes only yearling and older fish.

sented in large numbers. For the period of May to September when such collections were made in both years, the proportion of yellow perch dropped from about 71 to 6 per cent while that of black crappies increased from about 30 to 93 per cent. However, the catch of fingerling pumpkinseeds was negligible in both years.

Comparative growth rates between the period of the present study and earlier years, in terms of length in June, were given in Table 3 for yellow perch, pumpkinseeds, northern pike, largemouth bass and smallmouth bass. Similar comparisons between 1975 and 1978 during the present study, in terms of length in May, are given in Table 6 for yellow perch, black crappies, pumpkinseeds, bluegills and rock bass—the species for which representation of age groups during this period was adequate for meaningful comparison. The samples from gillnet and trawl collections were combined in each case. With few exceptions, there were no significant differences (t test: $P = 0.05$) between the two years for these species.

The relative abundance of different age groups for the principal species collected in 1975, 1978 and 1979 (Table 7) suggests a correlation with year-class strength. In 1978, the age 3 group (1975 year class) was the most abundant for all species except pumpkinseed. Although the 1979 sample was small and based on trawl and electrofishing collections in June, a similar pattern was evident with age 4 fish (again the 1975 year class) the most abundant for the species sampled except pumpkinseed. In 1975, there were sufficient data only for the yellow perch, black crappie and pumpkinseed populations. Yellow perch and pumpkinseeds, at age 3, ex-

TABLE 5. NUMBER AND PROPORTION OF THE CATCH OF YOUNG-OF-THE-YEAR FISH TAKEN IN TRAWL COLLECTIONS IN BLACK LAKE IN 1975 AND 1978, ACCORDING TO MONTH FOR THE MOST ABUNDANT SPECIES*

Species	May		June		July		August		September		October		Total	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
1975														
Yellow perch	0	. .	0	. .	1,610	98.4	220	26.0	16	13.4	441	99.8	2,287	75.1
Black crappie	0	. .	0	. .	27	1.6	616	72.8	103	86.6	1	0.2	747	24.6
Pumpkinseed	0	. .	0	. .	0	. .	10	0.2	0	. .	0	. .	10	0.3
Total	0	. .	0	. .	1,637	100.0	846	100.0	119	100.0	442	100.0	3,044	100.0
1978														
Yellow perch	0	. .	5	100.0	24	51.1	32	3.2	2	4.8	0	. .	63	5.7
Black crappie	0	. .	0	. .	22	46.8	965	95.8	40	95.2	0	. .	1,027	93.3
Pumpkinseed	0	. .	0	. .	1	2.1	10	1.0	0	. .	0	. .	11	1.0
Total	0	. .	5	100.0	47	100.0	1,007	100.0	42	100.0	0	. .	1,101	100.0

*As indicated in Table 4.

TABLE 6. COMPARATIVE GROWTH RATES IN 1975 AND 1978 FOR FIVE SPECIES IN BLACK LAKE AS INDICATED BY COLLECTIONS DURING MAY

Species	Year	Mean total length (millimeters) according to age (years)								
		1	2	3	4	5	6	7	8	9
Yellow perch	1975	86	136	165	188	212	217	269	272	275
	1978	85	128	155	184	192	. .	226	. .	. .
Black crappie	1975	72	124	172	215	. .	. .	. .	. .	. .
	1978	. .	130	174	214	233	252	. .	. .	. .
Pumpkinseed	1975	. .	108	127	144	164	181	. .	. .	. .
	1978	. .	. .	136	147	158	169	. .	. .	. .
Bluegill	1975	. .	104	153	180	215	. .	. .	. .	. .
	1978	. .	. .	. .	. .	188	. .	. .	. .	. .
Rock bass	1975	. .	. .	116	150	183	. .	. .	. .	. .
	1978	. .	92	133	174	. .	189	. .	. .	. .

TABLE 7. AGE STRUCTURE OF THE PRIMARY FISH POPULATIONS IN BLACK LAKE IN 1975, 1978 AND 1979 AS INDICATED BY THE COLLECTIONS MADE

Species	Total number*	Age§								
		1	2	3	4	5	6	7	8	9
1975										
Yellow perch	901	7	21	50	19	2	1	1	1	1
Black crappie	124	41	19	19	19	1	2	. .	. .	. .
Pumpkinseed	626	2	16	41	28	9	3	1	. .	. .
1978										
Largemouth bass	12	8	. .	58	8	. .	. .	17	. .	8
Smallmouth bass	35	. .	17	57	17	. .	6	3	. .	. .
Yellow perch	1,085	28	5	54	8	. .	2	1	. .	. .
Black crappie	922	15	2	74	7	2	. .	. .	. .	. .
Pumpkinseed	767	1	8	19	34	33	6	. .	. .	. .
Bluegill	34	. .	3	38	18	21	15	3	3	. .
1979†										
Smallmouth bass	31	. .	26	10	65	. .	. .	. .	. .	. .
Yellow perch	79	. .	4	23	51	16	12	. .	. .	. .
Black crappie	15	7	13	13	67	. .	. .	. .	. .	. .
Pumpkinseed	43	2	2	5	37	44	9	. .	. .	. .

*Figures less than totals for these species in Table 4 because not all specimens collected were measured, except for largemouth bass and smallmouth bass in 1978 for which 2 and 12 specimens, respectively, taken in trapnets during late May are included here although they are not considered elsewhere in this paper.

§Figures represent percentage (rounded) of total specimens in each case.

†Data included although sample was small and based only on trawl and electrofishing collections in June.

hibited strong 1972 year classes, but there was no apparent correlation for the black crappie.

The pattern of several species developing numerically dominant year classes in the same year has also been observed in two other eutrophic waters (Moon Lake and Muskellunge Lake) in the Indian River Lakes system having a fish population composition similar to that in Black Lake

(Schiavone, unpublished). Production of dominant year classes may be cyclical and related to the dynamics of the black crappie population. Goodson (1966) in California and Bennett (1944) in Illinois reported patterns of cyclic production of dominant year classes in lakes with a species composition similar to that in Black Lake. They felt that dominant year classes were the result of interspecific competition between crappies and the other species present. Both speculated that a new dominant year class of crappies was formed immediately following the disappearance of the previous one.

Studies by Keast (1965, 1968), Keast and Webb (1966) and Seaburg and Moyle (1964) indicated that crappies may compete with yellow perch, pumpkinseeds and other panfish, as well as bass, for invertebrate and small fish forage. They are predators on the young of most species, including their own, and they have the ability through morphological adaptations to effectively alter their foraging patterns as preferred food items become less abundant. Ercole (1969) reported that black crappies consumed significant quantities of largemouth bass fry in Arizona lakes. In a review of the literature on white crappies and black crappies, Ming (1971) concluded that the black crappie is the more prone to overpopulate its habitat and suppress populations of cohabiting species in shallow, productive lakes.

In Black Lake, the dominant 1975 year classes, observed at age 3 in 1978 and at age 4 in 1979 (Table 7), were produced when the relative abundance of adult crappies was low. Presumably, the strong year classes were formed at a time when crappie competition and predation were low. In 1975, 2.5 times as many fingerlings were collected as during the same period in 1978. The major difference between the two years was low production of yellow perch in 1978 in spite of the presence of a large 1975 year class. Keast (1968) reported that fish forage, primarily yellow perch, pumpkinseeds and bluegills, was important in the diet of crappies more than 115 millimeters long. Of the fish species that could be identified in his study, 33 to 50 per cent were yellow perch ranging in size from fry to 60 millimeters long. With the strong 3-year age group of crappies in 1978 having a mean length of 174 millimeters in May, crappie predation may have contributed significantly to the low abundance of yellow perch fingerlings. It would also seem that the phenomenon of largemouth bass, smallmouth bass and bluegills all producing strong year classes at the same time as black crappies may have been due to predation.

It is not clear if the low relative abundance of yearling and older crappies in 1975 was due to the absence of a dominant year class in 1974. If this were the case, the large 1975 year classes of pumpkinseeds and yellow perch would not have been expected if crappies suppress recruitment of other species and themselves through a strict predator-prey mechanism. It seems likely that the species interactions that result in production of domi-

nant year classes are more complex than those suggested by Goodson (1966) and Bennett (1944).

DISCUSSION

While there were no obvious changes in water quality over the study period, sedimentation may have resulted in an increase in the area of aquatic vegetation. Odell (1932) characterized Black Lake in 1931 as having extensive areas of aquatic vegetation, particularly in its large bays and lower arm The main basin had rock and sand shoals along the shoreline and numerous islands, with a mud bottom in the offshore, deeper areas. While it is not possible to document increases in vegetated areas, as early as the late 1940's businessmen and sportsmen began to report increased aquatic growth on shoal areas (State Department of Environmental Conservation, unpublished). With three large tributaries and a total drainage area of 1,410 square kilometers (U.S. Environmental Protection Agency, 1972), a significant loss of clean shoal areas through sedimentation and an increase in aquatics may have occurred and may explain the apparent decline in the abundance of rock bass (Table 2) which began before the introduction of black crappies. On the other hand, with the Indian River and Fish Creek (Figure 1) historically supporting large walleye spawning runs, it seems unlikely that the loss of clean shoal areas in the lake would have significantly affected walleye spawning success.

The walleye population in Oneida Lake has been studied intensively, and the results are assumed to be applicable to the population in Black Lake. In Oneida Lake, walleye fry became pelagic after hatching and fed largely on zooplankton (Noble, 1975). They fed largely on copepods until they reached a length of 10 millimeters when yellow perch fry became important (Houde, 1967). Perch fry and fingerlings remained important in the diet of post-pelagic walleyes (Forney, 1966). The walleye-yellow perch association is complex, with yellow perch abundance and growth, largely determined by the abundance of zooplankton, being related to walleye year-class formation, growth and exploitation (Forney, 1978). Forney (1978) also reported that walleyes were more vulnerable to angler exploitation when perch abundance was low.

The feeding and habitat preferences of black crappies provide insight into possible walleye-black crappie interactions. Studies by Faber (1967) and Keast (1965) indicated that the larval through adult stages of the black crappie use the same habitat as walleyes. Published literature and data collected during the present study suggest that predation by crappies has been a significant factor in yellow perch year-class formation. Since walleye and yellow perch fry behave similarly in the early stages of their life history, it may be assumed that black crappie predation could adversely affect walleye recruitment.

It seems likely that the decline in the walleye population in Black Lake resulted from the introduction of black crappies at a time when a period of unstable walleye recruitment may have allowed the crappies to produce large year classes. Based on tag-return data from the 1960's and early 1970's (State Conservation Department, unpublished) the walleye fishery at that time was intense. Competition with strong year classes of crappies for the available forage fish may have incresed the vulnerability of the walleyes and resulted in a proportionally larger angler harvest of adult fish. Continued angler exploitation, a reduced spawning population and crappie predation on walleye fry may have led to the successive year-class failures observed in the 1970's (Schiavone, 1981) and allowed the black crappie to achieve its current dominant position in the fish community.

Comparison of the growth rates of northern pike, largemouth bass and smallmouth bass in the 1950's with those in the 1970's indicated that changes had taken place. While the abundance of northern pike was low in the gillnet collections in 1975 and 1978, a significant increase in their growth has occurred since 1950. The increase may have been due to greater availability of larger prey items following the decline of the walleye population. During the same period, growth rates of largemouth bass and smallmouth bass decreased slightly, possibly as a result of competition from black crappies. The three species were not collected in sufficient numbers in any of the sample years to evaluate changes in abundance following the walleye decline. The age structure among the bass collected in 1978 and 1979 suggested that recruitment may have been influenced by the dynamics of the crappie population.

The increases in growth rate for yellow perch and pumpkinseeds cannot be readily explained. They may have been a result of changes in the trophic structure of the fish community. With the decline of the walleye, rock bass, white sucker, redhorse sucker, mooneye and bowfin populations, species interactions may have changed in a manner that permitted yellow perch and pumpkinseeds to increase their growth rates while apparently maintaining similar levels of abundance.

The results of this study indicate that the black crappie has been a major influence on the structure and dynamics of the Black Lake fish community. Additional studies would be needed to clarify species interactions that result in the observed age-structure pattern, as well as to further relate the dynamics of the northern pike and bass populations to that of the panfish species. Trawl collections adequately sample black crappie, pumpkinseed and yellow perch populations and allow estimation of relative abundance, growth and age structure. The results of sampling in 1979 suggest that seining and electrofishing for bass and trapnetting for spawning northern pike might provide the data necessary to develop a more complete understanding of the dynamics of the fish community. With major changes having occurred in the last 10 years, the Black Lake fish com-

munity may still be in a state of transition. Knowledge of changes from 1931 to 1979 and of the dynamics of the community in the 1970's should be useful in planning future management for Black Lake and similar waters.

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SUMMER DIET OF JUVENILE FISH IN THE ST. LAWRENCE RIVER[1]

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ABSTRACT

During August 1976 the stomach contents of 237 juvenile fish representing nine species from three locations along the St. Lawrence River were examined. The major food items identified in the order of percentage contribution by weight to the diet were chironomids, cladocerans, amphipods, corixids and fish. In these waters young-of-the-year largemouth bass become pisciverous by the time they are 60 millimeters long. Diet overlap was found to be significant in 11 comparisons involving eight of the nine species. The greatest overlap occurred between juvenile smallmouth bass, yellow perch and pumpkinseeds. The lowest was between largemouth bass (a piscivore) and alewife (a planktivore).

Construction of the St. Lawrence Seaway in the late 1950's changed not only the physical characteristics of the river but also the nature of the fishery. The extensive areas of rapids that had existed below Ogdensburg were completely flooded and eliminated. Their disappearance may have led to the decline of the walleye (*Stizostedion vitreum*) and lake sturgeon (*Acipenser fulvescens*) which had occupied these habitats. Also, construction of the Moses-Saunders Power Dam near Massena may have severed migration routes that these species used to complete their reproductive cycles.

Although the walleye and lake sturgeon populations in the section below Ogdensburg have presumably suffered from environmental disturbances caused by construction and operation of the Seaway, other species have flourished in the upper river. The St. Lawrence River ranks first in the State in terms of angler harvest of largemouth bass (*Micropterus salmoides*), northern pike (*Esox lucius*) and muskellunge (*Esox masquinongy*), and second with respect to smallmouth bass (*Micropterus dolomieui*), brown bullhead (*Ictalurus nebulosus*) and panfish, based on the findings of Brown (1976). According to the same author, it ranks second only to Oneida Lake in terms of a warmwater sport fishery and fourth in total angler days.

As a result of a proposal to extend the navigation season on the Great

[1]The study was funded through the pilot study program of the U.S. Fish and Wildlife Service during 1976 concerning winter navigation on the Great Lakes. The author wishes to acknowledge Thomas Eckert of the State Department of Environmental Conservation fisheries station at Cape Vincent who supplied the fish examined, Dr. Neil Ringler of the State University of New York at Syracuse who furnished analytical and supervisory assistance, and Emily Zebisch of the State University of New York at Syracuse and Edward Radle of the State Department of Environmental Conservation who reviewed the manuscript.

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Lakes, a program was begun in 1976 to gather baseline biological information on the fisheries resources of the river to aid in assessing the potential impact of winter navigation. One phase of the investigation pertained to the summer feeding habits of fish in the river. These studies were designed to determine the major foods of both juvenile and adult fish as well as the relative amounts eaten. No data of this sort had been published since construction of the Seaway, and for conditions prior to that only the limited information reported by Sibley and Rimsky-Korsakoff (1930) was available. The present paper presents the findings for juvenile fish.

METHODS AND MATERIALS

Fish were collected in New York waters near Cape Vincent, Morristown and Massena (Figure 1) during August 1976. Collections were made with beach seines of ¼-inch bar mesh 36 feet long by 6 feet wide. The juvenile fish taken were immediately placed in 10 per cent formalin, while older fish were released alive whenever possible. Species collected in insufficient number to measure the composition of their diets are not reported.

In the laboratory the fish were weighed and measured (total length) and their stomach contents was examined under a stereo-microscope. The food items found were identified to family for aquatic insects and to various

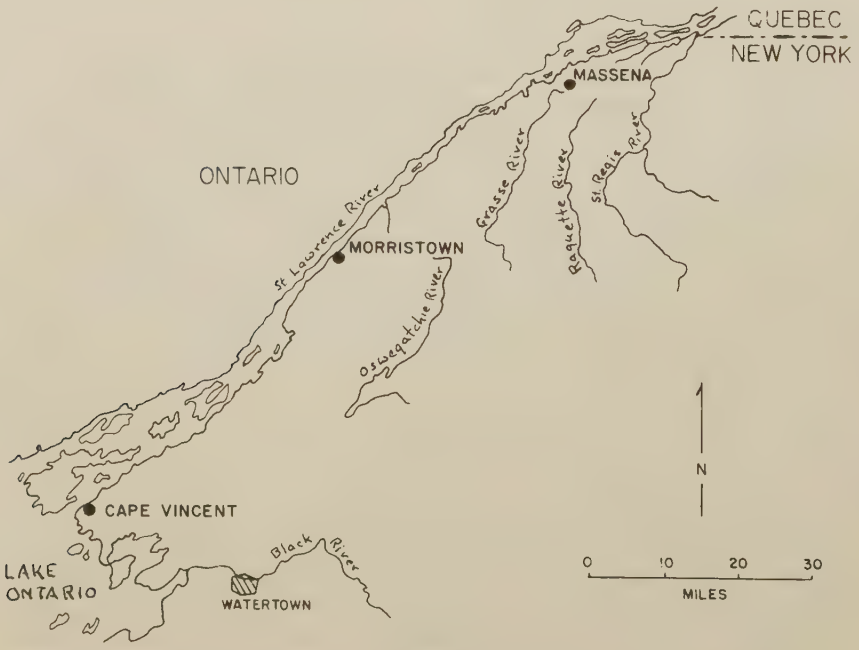

Figure 1. Section of St. Lawrence River showing location of Cape Vincent, Morristown and Massena where fish were collected.

levels for other prey, and their dry weights were determined. A representative number of individuals of each taxon were dried at 105° C. for 24 hours, placed in a desiccator for 8 hours and then weighed. The mean of the sample was then multiplied by the number of individuals in the stomach. For each fish species at each collection site, the data were combined, and the relative contribution of each food category to the diet was estimated as its proportion of the total.

Values for diet overlap (i.e., the degree to which the composition of the diet is the same among different groups) were calculated according to the equation of Morisita (1959) as modified by Horn (1966)

$$C\lambda = 2 \frac{\sum_{i=1}^{s} XiYi}{\sum_{i=1}^{s} Xi^2 + \sum_{i=1}^{s} Yi^2}$$

where:

$C\lambda$ = overlap value

s = total items in both categories

Xi = proportion of total diet of fish species X contributed by food taxon i

Yi = proportion of total diet of fish species Y contributed by food taxon i

RESULTS

A total of 237 juvenile fish representing nine species were examined. Over half of these specimens (125) were collected in the lower part of the study section near Massena, whereas 57 were collected near Morristown and 55 near Cape Vincent.

In the vicinity of Cape Vincent only subyearling largemouth bass, rock bass (*Ambloplites rupestris*) and alewives (*Alosa pseudoharengus*) were collected in sufficient numbers to warrant analysis. The data are summarized in Table 1. Fish and amphipods were the major foods taken by the largemouth bass. Rock bass fed mainly on chironomid larvae and pupae, cladocerans and water mites (*Hydracarina*), whereas the alewives primarily ate cladocerans.

Largemouth bass, smallmouth bass, brown bullheads and yellow perch (*Perca flavescens*) were collected near Morristown. These samples included both 0 + and I + fish. The data are summarized in Table 2. Corixids, amphipods and baetid mayflies were the major prey eaten by the largemouth

TABLE 1. STOMACH CONTENTS OF JUVENILE FISH COLLECTED IN THE ST. LAWRENCE RIVER NEAR CAPE VINCENT DURING AUGUST 1976

Food	Percentage of dry weight		
	Largemouth bass	Rock bass	Alewife
Invertebrates			
Cladocera	. .	20.52	96.64
Copepoda	. .	0.75	1.60
Ostracoda	. .	2.99	0.25
Hydracarina	. .	17.91	. .
Amphipoda	19.24	12.69	. .
Leptoceridae	. .	0.37	. .
Chironomidae	2.38	44.40	1.51
Lepidoptera	. .	0.37	. .
Fish			
Alewife (postlarvae)	7.13	. .	. .
Unidentified	71.25	. .	. .
Total	100.0	100.0	100.00
Number of fish examined	15	20	20
Length (millimeters)			
Mean	59	34	49
Range	35-68	30-38	39-57

TABLE 2. STOMACH CONTENTS OF JUVENILE FISH COLLECTED IN THE ST. LAWRENCE RIVER NEAR MORRISTOWN DURING AUGUST 1976

Food	Percentage of dry weight			
	Largemouth bass	Smallmouth bass	Brown bullhead	Yellow perch
Planariidae	. .	. .	. .	0.87
Hirudinea	. .	. .	. .	5.43
Cladocera	. .	0.55	0.75	0.24
Copepoda	. .	0.07	5.45	0.01
Ostracoda	. .	0.02	2.22	0.67
Hydracarina	. .	. .	0.13	0.29
Isopoda	. .	. .	30.27	2.96
Amphipoda	37.77	69.83	30.54	49.17
Baetidae	10.58	. .	2.82	. .
Caenidae	4.91	. .	2.62	. .
Corixidae	42.49	. .	4.54	. .
Trichoptera (pupae)	. .	5.81	. .	. .
Hydroptilidae	. .	. .	. .	3.59
Dytiscidae	. .	. .	2.72	. .
Chironomidae	1.89	23.72	17.15	33.68
Ceratopogonidae	. .	. .	0.79	. .
Syrphidae	. .	. .	. .	0.78
Gastropod	. .	. .	. .	0.26
Planorbidae	. .	. .	. .	0.34
Physidae	. .	. .	. .	0.52
Hydrobiidae	. .	. .	. .	0.48
Homoptera	. .	. .	. .	0.71
Hymenoptera	2.36	. .	. .	. .
Total	100.00	100.00	100.00	100.00
Number of fish examined	7	20	10	20
Length (millimeters)				
Mean	71	42	74	103
Range	63-77	30-50	60-92	95-114

TABLE 3. STOMACH CONTENTS OF JUVENILE FISH COLLECTED IN THE ST. LAWRENCE RIVER NEAR MASSENA DURING AUGUST 1976

Food	Percentage of dry weight						
	Largemouth bass	Smallmouth bass	Black crappie	Pumpkinseed	Yellow perch	White perch	Alewife
Invertebrates							
Cladocera	..	..	15.38	1.62	0.04	40.69	83.85
Copepoda	..	..	..	..	0.02	34.12	11.38
Ostracoda	..	..	1.28	2.06	0.03	6.03	1.60
Hydracarina	..	..	..	..	0.08	0.05	0.01
Amphipoda	..	5.56	4.70	0.44	8.20	0.34	0.10
Collembola	..	..	..	..	..	..	0.01
Emphemeridae	..	..	..	..	..	0.33	..
Baetidae	..	..	..	..	..	0.05	..
Coenagrionidae	..	1.85	..	..	..	..	..
Leptoceridae	..	..	..	..	..	0.05	..
Hydroptilidae	..	..	..	1.50	..	0.10	..
Corixidae	47.09	9.26	37.18	0.32	2.68	7.10	..
Chironomidae	8.07	74.07	41.03	93.63	87.28	10.99	3.05
Ceratopogonidae	..	..	..	0.06	..	0.10	..
Gastropoda	..	..	..	..	0.33	..	..
Diptera (aerial)	..	..	..	..	1.34	..	..
Homoptera	..	..	..	0.06	..	..	..
Lepidoptera	..	..	..	0.31	..	..	..
Fish							
Etheostoma spp.	..	1.86	..	..	..	..	..
Unidentified	44.84	7.40	0.43	..	..	0.05	..
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Number of fish examined	10	15	20	20	20	20	20
Length (millimeters)							
Mean	66	99	110	88	122	119	100
Range	61-72	57-137	100-135	77-113	106-143	109-134	91-109

Table 4. Diet Overlap Between Juvenile Fish of Different Species Examined From the St. Lawrence River During August 1976, According to Collection Site

Species	Overlap value
Cape Vincent	
Rock bass-alewife	0.3356
Largemouth bass-rock bass	0.0835
Largemouth bass-alewife	0.0005
Morristown	
Smallmouth bass-yellow perch	0.9324*
Brown bullhead-yellow perch	0.7449*
Smallmouth bass-brown bullhead	0.6603*
Largemouth bass-smallmouth bass	0.6062*
Largemouth bass-yellow perch	0.5501
Largemouth bass-brown bullhead	0.5078
Massena	
Yellow perch-pumpkinseed	0.9929*
Smallmouth bass-yellow perch	0.9784*
Smallmouth bass-pumpkinseed	0.9612*
Smallmouth bass-black crappie	0.7586*
White perch-alewife	0.7536*
Yellow perch-black crappie	0.6751*
Black crappie-pumpkinseed	0.6417*
Largemouth bass-black crappie	0.5465
White perch-black crappie	0.4249
Largemouth bass-smallmouth bass	0.2743
Black crappie-alewife	0.2700
Smallmouth bass-white perch	0.2030
White perch-pumpkinseed	0.1881
Yellow perch-white perch	01835
Largemouth bass-yellow perch	0.1386
Largemouth bass-pumpkinseed	0.1179
Largemouth bass-white perch	0.0928
Pumpkinseed-alewife	0.0533
Yellow perch-alewife	0.0364
Smallmouth bass-alewife	0.0353
Largemouth bass-alewife	0.0043

*Denotes significant overlap.

bass. Amphipods and chironomids were the major food of the smallmouth bass, brown bullheads and yellow perch. The only additional prey of importance were isopods which contributed 30 per cent to the diet of the bullheads.

Near Massena, the species collected in sufficient numbers for analysis were largemouth bass, smallmouth bass, black crappie (*Pomoxis nigromaculatus*), pumpkinseed (*Lepomis gibbosus*), yellow perch, white perch (*Morone americana*) and alewife. The data are summarized in Table 3. Subyearling largemouth bass fed mainly on corixids and fish. Chironomids and corixids were the major foods of the predominately yearling smallmouth bass and yearling black crappie. Pumpkinseeds and yellow perch fed almost exclusively on chironomids. Cladocerans and copepods were the primary prey of the white perch and alewives.

The degree of overlap among the juvenile fish examined in each area is summarized in Table 4. Overlap values ($C\lambda$) can vary from 0, when samples contain no foods in common, to 1, when there is identical propor-

tional representation between samples in the foods eaten. The three comparisons for fish collected near Cape Vincent showed little similarity in diet. Diet overlap was highest at the Morristown site where the lowest value was that between largemouth bass and brown bullhead. The greatest variability occurred at the Massena site, possibly because the most species were represented. Information on the diet overlap between two species at more than one site was obtained in only four instances: (1) largemouth bass-alewife at Cape Vincent and Massena; (2) largemouth bass-yellow perch at Morristown and Massena; (3) largemouth bass-smallmouth bass at Morristown and Massena; (4) smallmouth bass-yellow perch at Morristown and Massena. Although the number of fish examined was small, these data suggest that similarity in diet was greatest between juvenile smallmouth bass and yellow perch, and least between largemouth bass and alewives. Diet overlap between largemouth bass and smallmouth bass was slightly greater than that between largemouth bass and yellow perch. Pumpkinseeds were collected only at Massena where there was a high diet overlap between them and both smallmouth bass and yellow perch.

DISCUSSION

Calculated from the equation used here, overlap values of 0.60 or more are considered significant (Zaret and Rand, 1971). Such overlaps were observed in 67 per cent of the comparisons for the fish collected near Morristown and in 33 per cent of those from the Massena site (Table 4). There was no significant overlap for the fish collected near Cape Vincent.

Similar use of chironomids and amphipods by the smallmouth bass and yellow perch at Morristown and Massena was the major reason for the significant overlap in their diets. Most other significant overlaps between species reflected extensive predation on chironomids. The only significant overlap not due to heavy use of chironomids and amphipods was that between white perch and alewives at Massena where it was the result of similar predation on cladocerans and copepods. The lowest overlap occurred between the largemouth bass (a piscivore) and alewife (a planktivore).

Data from Cape Vincent and Massena suggest that young-of-the-year largemouth bass become piscivorous by the time they reach 60 millimeters in total length, which agrees with the findings of Turner and Kraatz (1920) and Moyle and Holzhauser (1978). However, other investigators (Keast, 1970; Clady, 1974) observed this transition at larger sizes. Corixids, a surface-dwelling hemipteran which comprised 42 per cent and 47 per cent of the diets of young-of-the-year largemouth bass from Morristown and Massena, respectively, have previously been found to be heavily used by young largemouth bass (Turner and Kraatz, 1920; Applegate and Kruckenberg, 1978; Moyle and Holzhauser, 1978).

The diet of young-of-the-year smallmouth bass collected near Morris-

town varied somewhat from that reported by Clady (1974) who found that chironomids and entomostracans were the primary food of such bass in two northern Michigan lakes during late summer. However, in the St. Lawrence River amphipods were the major prey (70 per cent) of the young-of-the-year smallmouth bass (collected chiefly at Morristown). Chironomids, which were the major food (74 per cent) of the predominately yearling smallmouth bass collected near Massena were also important to the diet of juvenile smallmouth bass in Michigan (Clady, 1974).

The diet of juvenile yellow perch at both the Morristown and Massena sites was similar to that reported by Keast (1977) and Clady (1974) who found that chironomids were the major food during late summer. The diet of the brown bullheads collected near Morristown was diverse with nine prey taxa each comprising at least 2 per cent. Extensive use of zooplankton by young brown bullheads as reported by Keast and Webb (1966) in Lake Opinicon, Ontario, was not observed. The major foods of yearling black crappie and young-of-the-year rock bass were similar to those found by Keast (1968, 1970). A predominance of zooplankton in the diet of young white perch and young alewives (under 119 millimeters in total length) was reported by Webster (1943) and Morsell and Norden (1968), respectively.

High degrees of diet overlap in 11 comparisons involving eight of the nine species studied suggest that these fish were making use of similar prey. The major prey taxa, in order of use, were chironomids, cladocerans, amphipods, corixids and fish. There were differences in use by some species in different sections of the river. For example, corixids contributed 40 per cent to the diet of young-of-the-year largemouth bass at both Morristown and Massena but were absent from the diet at Cape Vincent. Furthermore, limited data suggest that differences in diet occurred between year classes of smallmouth bass. Young-of-the-year smallmouth bass at Morristown fed mainly on amphipods (70 per cent), whereas at Massena the primarily yearling fish fed on chironomids (74 per cent). The fact that all four species examined from Morristown contained large quantities of amphipods indicates that certain prey may be locally important to juvenile fish in the St. Lawrence River.

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THE FISHES OF FORT POND BAY ON LONG ISLAND, NEW YORK[1]

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ABSTRACT

The seasonal occurrence, abundance and species composition of the ichthyofauna of Fort Pond Bay on Long Island were studied from 1970 to 1975. Specimens of 102 species representing 53 families were recorded, primarily collected by pound net. Variations in abundance and composition were characteristic of the spring, summer and fall seasons. Species composition and distribution as an indicator of environmental change is discussed. Since Fort Pond Bay is part of an area where the environment is considered relatively unmodified, the data presented should serve as a yardstick against which to measure future conditions.

The marine ichthyofauna of eastern Long Island, New York, has not been defined in any detail since the accounts of fishes at Orient by Roy Latham during the second and third decades of this century and the work of Nichols and Breder (1926) for which Latham's data were the major source. In his account of the marine fishes of New York and southern New England, Gordon (1951) gave the status of many species in the waters of Block Island Sound, the Peconic Bays and Gardiner's Bay as unknown or unrecorded. Other brief or specialized accounts of the fishes in eastern Long Island waters were given by Bean (1901, 1903), Murphy and Harper (1915), Greeley (1939), Perlmutter (1939), Bigelow and Schroeder (1953), Austin (1973) and Reisman and Nichol (1974). Recently the present authors noted the occurrence of several previously unreported species at Fort Pond Bay, as well as numerous species whose origin and primary distribution are in southern waters (Hickey and Lester, 1975, 1980; Hickey et al., 1975, 1976). The present study provides additional information concerning the Montauk area.

METHODS

Fort Pond Bay, situated on the northern side of the easternmost extremity of Long Island, is south of Block Island Sound and southeastward across Gardiner's Bay from Orient Point (Figure 1). The fishes listed here are primarily those captured by the second author in two pound nets (mesh

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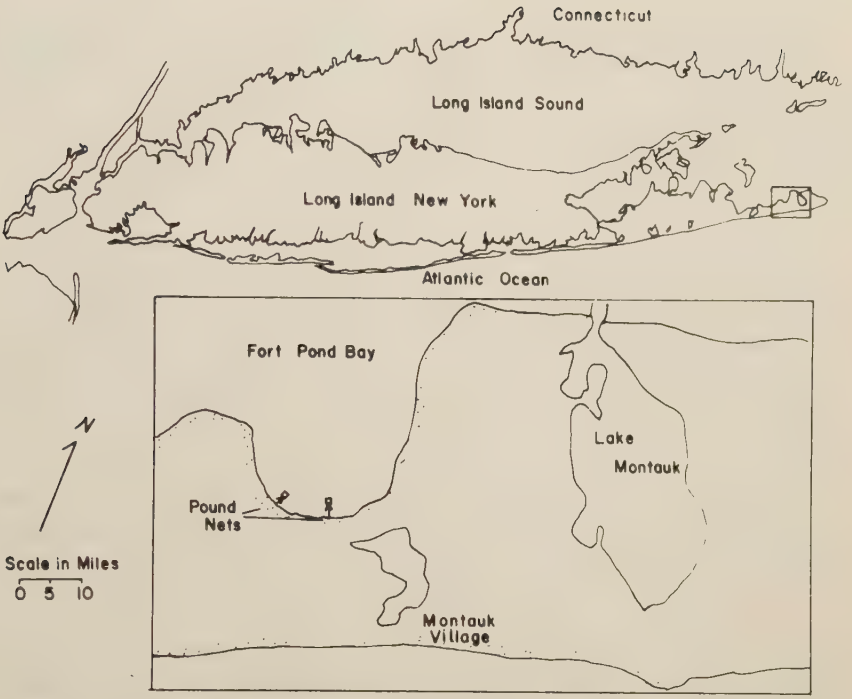

Figure 1. Map of Long Island showing location of Fort Pond Bay and enlargement showing location of pound nets used in this study.

sizes 2 to 6 inches) operated near the southern beach of Fort Pond Bay during the 6-year period from June 1, 1970 to December 10, 1975. Other species are noted that were either observed by the authors or brought to their attention by interested persons.

Pound-net fishing begins in April or May and usually runs through October or early November. In 1975, however, it continued through early December, although the nets were tended on only three occasions during that month. Prior to April and after November, fish were not numerous and the weather was inclement (Hickey and Lester, 1980).

The pound-net method of collecting fish to assess species occurrence and relative abundance was considered satisfactory. The nets were stationary, operated in the same locations year after year and tended three to seven days each week during the fishing season. Due to the large mesh size of the nets used, however, small fish were not captured, especially attenuated forms such as the bay anchovy, Atlantic silverside and sand lance. Their abundance was noted by observation and by collection with other gear, primarily dip net and beach seine. Rock gunnel were observed among the mussel-barnacle-algae communities around docks and pilings. Spotfin butterflyfish and small-sized short bigeye were observed and collected by skin diving. The seasonal occurrence, abundance and species composition

of the ichthyofauna of Fort Pond Bay were rather distinct, and thus the seasons can be described not only by physical parameters but also by the composition of the fish population. Spring, here considered to be April, May and June, is marked by the appearance of resident and migratory temperate species, along with rapidly warming water temperatures. Summer (July, August and early September) is marked by a decrease in the abundance or availability of "spring" species and the appearance of species of southern origins. During this period, water temperatures warm more slowly and reach the yearly maximum. Fall (late September, October and November) is marked by an increase in the abundance of resident and migratory temperate fishes, as well as the presence of large numbers of juveniles of some species, and their subsequent departure along with the species of southern origins. Water temperatures begin cooling rapidly during this period. The monthly temperature regime at Fort Pond Bay was discussed by Hickey and Lester (1980).

The abundance of each species is reported for each season as the average for the 6-year period. It is given in relative terms, similar to those used by Nichols and Breder (1926), Gordon (1951) and Holden and Stalnaker (1975), as follows:

Abundant	Species was captured or observed on numerous occasions in large quantities; often several size classes were present.
Common	Species was captured or observed on several occasions in moderate to large quantities; often several size classes were present.
Occasional	Species was captured or observed periodically and in small quantities; size classes were more homogeneous than in the foregoing categories.
Rare	Species was captured or observed only rarely; usually only one or a few individuals constituted the catch.
Absent	Species was neither captured nor observed; absence of a species in or around the pound nets did not necessarily rule out its presence in Fort Pond Bay but did suggest that it was extremely rare.

Yearly and seasonal fluctuations in abundance were often quite evident. During the spring of 1972, for example, striped bass were more abundant than during any other spring of the study. They were predominantly age II fish of the very numerous 1970 year class in Chesapeake Bay noted by Austin and Hickey (1974, 1978). Similarly, the unusually warm summer of 1973 produced more captures of fishes of southern origins than any other summer during the study. A study of variables affecting striped bass

migrations showed that meteorological conditions can influence the presence and abundance of the species in Fort Pond Bay (Hickey, 1981). Therefore, when interpreting the seasonal abundance described here, one should allow for natural fluctuations due to year-class abundance and environmental variations.

RESULTS AND DISCUSSION

During the 6-year period of study, 100 species representing 53 families were recorded at Fort Pond Bay. In addition, two species were captured in the pound nets after December 1975: a coho salmon[2] taken on November 28, 1977 and a timucu taken in July 1978. The seasonal occurrence and relative abundance of these species are summarized in Table 1. Although other species may frequent Fort Pond Bay, it is felt that the list presented includes very nearly all of those that occur there. The nomenclature used is that of Bailey et al. (1970).

Fort Pond Bay is an open body of water probably best described as an oceanic embayment, since its temperature/salinity/chemistry regime follows closely that of adjacent Block Island Sound. As such, the composition of the fish population (except for a few species) may be representative of that in the adjacent waters and vice versa. Fishes that are captured seasonally in Block Island Sound but were not observed during this study include the shortfin mako (*Isurus oxyrinchus*), dusky shark (*Carcharhinus obscurus*), blue shark (*Prionace glauca*), swordfish (*Xiphias gladius*), billfishes (*Istiophoridae*) and yellowtail flounder (*Limanda ferruginea*).

The family Carangidae, representing 11 species, was the most diverse of those recorded, followed by the Scombridae (7 species), Clupeidae (6), Gadidae (5) and Sciaenidae (5). All other families were represented by one to three species each. Of the 102 species observed, 15 comprised the majority by numbers (and probably biomass) of all the fish taken: smooth dogfish, little skate, Atlantic menhaden, bay anchovy, Atlantic silverside, striped bass, bluefish, scup, weakfish, sand lance, Atlantic mackerel, butterfish, northern searobin, striped searobin and winter flounder. Juveniles of several species were abundant, particularly during the summer and fall. The fall catches of bluefish, blue runner, weakfish, Atlantic mackerel and butterfish were almost entirely juveniles. Juvenile striped bass were present during all three seasons, but they dominated the catch only during the spring.

Several species of amphipod crustaceans were very abundant in Fort Pond Bay during the spring, especially *Gammarus annulatus* and

[2]The coho salmon is a native of west coast waters that has been introduced in the East. New York has stocked the species in the Carmans River on Long Island. Smolts have been released in New Hampshire since 1969 (Stolte, 1974) and in Massachusetts since 1971 (Symons and Martin, 1978).

TABLE 1. FISHES RECORDED IN FORT POND BAY FROM JUNE 1, 1970 TO DECEMBER 10, 1975 ACCORDING TO SEASON AND RELATIVE ABUNDANCE*

Family and species	Common name	Relative abundance§		
		Spring	Summer	Fall
Petromyzontidae				
Petromyzon marinus	Sea lamprey	. .	. .	R
Lamnidae				
Cetorhinus maximus	Basking shark	. .	. .	R
Carcharhinidae				
Mustelus canis	Smooth dogfish	A	A	O†
Squalidae				
Squalus acanthias	Spiny dogfish	. .	. .	O
Torpedinidae				
Torpedo nobiliana	Atlantic torpedo	R	. .	. .
Rajidae				
Raja eglanteria	Clearnose skate	. .	R	R
Raja erinacea	Little skate	A	O	A†
Dasyatidae				
Dasyatis centroura	Roughtail stingray	R	R	R
Gymnura micrura	Smooth butterfly ray	. .	R	. .
Myliobatidae				
Myliobatis freminvilli	Bullnose ray	. .	R	. .
Rhinoptera bonasus	Cownose ray	. .	. .	R
Mobulidae				
Manta birostris	Atlantic manta	. .	R	. .
Acipenseridae				
Acipenser sp.	Sturgeon	R	. .	. .
Elopidae				
Elops saurus	Ladyfish	. .	. .	R
Megalops atlantica	Tarpon	. .	R	. .
Anguillidae				
Anguilla rostrata	American eel	O	O	O
Congridae				
Conger oceanicus	Conger eel	O	O	O
Clupeidae				
Alosa aestivalis	Blueback herring	. .	. .	C
Alosa pseudoharengus	Alewife	O	. .	O
Alosa sapidissima	American shad	R	R	R
Brevoortia tyrannus	Atlantic menhaden	A	O	O†
Clupea harengus harengus	Atlantic herring	O	R	O
Etrumeus teres	Round herring	. .	. .	R
Engraulidae				
Anchoa mitchilli	Bay anchovy	O	. .	C†
Salmonidae				
Salmo gairdneri	Rainbow trout	. .	. .	R
Salmo salar	Atlantic salmon	R	R	. .
Oncorhynchus kisutch	Coho salmon	. .	. .	R
Osmeridae				
Osmerus mordax	Rainbow smelt	. .	. .	R

TABLE 1. *(continued)*

Family and species	Common name	Relative abundance§		
		Spring	Summer	Fall
Batrachoididae				
Opsanus tau	Oyster toadfish	. .	. .	O
Lophiidae				
Lophius americanus	Goosefish	R	R	C†
Gadidae				
Gadus morhua	Atlantic cod	R	. .	R
Merluccius bilinearis	Silver hake	C	. .	. .
Microgadus tomcod	Atlantic tomcod	R	. .	. .
Pollachius virens	Pollock	R	. .	R
Urophycis chuss	Red hake	O	. .	. .
Zoarcidae				
Macrozoarces americanus	Ocean pout	R	. .	. .
Belonidae				
Strongylura marina	Atlantic needlefish	. .	R	R
Strongylura timucu	Timucu	. .	R	. .
Antherinidae				
Menidia menidia	Atlantic silverside	C	A	C†
Syngnathidae				
Syngnathus fuscus	Northern pipefish	R	O	R
Percichthyidae				
Morone americana	White perch	R	. .	R†
Morone saxatilis	Striped bass	C†	O†	A†
Serranidae				
Centropristis striata	Black sea bass	O	R	R
Priacanthidae				
Priacanthus cruentatus	Glasseye snapper	. .	. .	R
Pristigenys alta	Short bigeye	. .	O	R
Pomatomidae				
Pomatomus saltatrix	Bluefish	O	C†	A†
Echeneidae				
Echeneis naucrates	Sharksucker	R	R	. .
Carangidae				
Alectis crinitus	African pompano	. .	R	. .
Caranx crysos	Blue runner	. .	C†	O†
Caranx hippos	Crevalle jack	. .	. .	O
Caranx latus	Horse-eye jack	. .	R	. .
Decapterus punctatus	Round scad	. .	R	. .
Selar crumenophthalmus	Bigeye scad	. .	C	R
Selene vomer	Lookdown	. .	R	R
Seriola zonata	Banded rudderfish	. .	O	O
Trachinotus carolinus	Florida pompano	. .	R	R
Trachinotus falcatus	Permit	. .	R	R
Vomer setapinnis	Atlantic moonfish	. .	R	R†
Lutjanidae				
Lutjanus cyanopterus‡	Cubera snapper	. .	R	. .

Table 1. *(continued)*

Family and species	Common name	Relative abundance§		
		Spring	Summer	Fall
Sparidae				
Calamus penna	Sheepshead	. .	R	. .
Lagodon rhomboides	Pinfish	. .	R	. .
Stenotomus chrysops	Scup	A	A†	O†
Sciaenidae				
Bairdiella chrysura	Silver perch	. .	R	R
Cynoscion regalis	Weakfish	C	C	A†
Leiostomus xanthurus	Spot	. .	. .	R
Menticirrhus saxatilis	Northern kingfish	C	O	O
Micropogon undulatus	Atlantic croaker	. .	R	. .
Ephippidae				
Chaetodipterus faber	Atlantic spadefish	. .	R	. .
Chaetodontidae				
Chaetodon ocellatus	Spotfin butterflyfish	. .	O	R
Labridae				
Tautoga onitis	Tautog	C	R	O
Tautogolabrus adspersus	Cunner	R	O	O
Mugilidae				
Mugil cephalus	Striped mullet	. .	. .	O
Sphyraenidae				
Sphyraena borealis	Northern sennet	. .	R	. .
Pholidae				
Pholis gunnellus	Rock gunnel	R	R	R
Ammodytidae				
Ammodytes sp.	Sand lance	A	R	R
Trichiuridae				
Trichiurus lepturus	Atlantic cutlassfish	. .	R	R
Scombridae				
Euthynnus alletteratus	Little tunny	. .	O	C
Sarda sarda	Atlantic bonito	R	O	. .
Scomber japonicus	Chub mackerel	R	R	. .
Scomber scombrus	Atlantic mackerel	A	O†	R†
Scomberomorus maculatus	Spanish mackerel	. .	O	O
Scomberomorus regalis	Cero	. .	. .	R
Thunnus alalunga	Albacore	. .	. .	O
Stomateidae				
Hyperoglyphe perciformis	Barrelfish	. .	R	. .
Peprilus alepidotus	Harvestfish	. .	R†	R†
Peprilus triacanthus	Butterfish	A	C	A†
Triglidae				
Prionotus carolinus	Northern searobin	A	O	C
Prionotus evolans	Striped searobin	A	O	C†
Cottidae				
Hemitripterus americanus	Sea raven	R	. .	R
Myoxocephalus octodecemspinosus	Longhorn sculpin	R	. .	R
Cyclopteridae				
Cyclopterus lumpus	Lumpfish	R	. .	. .

TABLE 1. *(continued)*

Family and species	Common name	Relative abundance§		
		Spring	Summer	Fall
Bothidae				
Paralichthys dentatus	Summer flounder	C	O	O
Paralichthys oblongus	Fourspot flounder	O	R	. .
Scophthalmus aquosus	Windowpane	O	O	C
Pleuronectidae				
Pseudopleuronectes americanus	Winter flounder	C	O	C
Soleidae				
Trinectes maculatus	Hogchoker	R	. .	. .
Balistidae				
Aluterus schoepfi	Orange filefish	R	R	R
Balistes capriscus	Gray triggerfish	R	R	. .
Monacanthus hispidus	Planehead filefish	. .	. .	R
Tetraodontidae				
Sphoeroides maculatus	Northern puffer	O	R	O†
Diodontidae				
Chilomycterus schoepfi	Striped burrfish	. .	R	. .
Molidae				
Mola mola	Ocean sunfish	. .	R	. .
Total species	102	51	69	71

*Also includes coho salmon and timucu recorded after December 1975 (see text).

§Data represent adult fish unless otherwise noted. Symbols as follows: A—abundant; C—common; O—occasional; R—rare.

†Both adults and juveniles present.

‡Reported and identified by Young (1978).

Calliopius laeviusculus in both the water column and on rocks and pilings. Also, *Jassa marmorata* and *Corophium volutator* were among the sessile and encrusting mussel-barnacle-alga communities. These and other amphipods comprised a large part of the food of many of the first fish species to arrive in the spring. They were eaten by small fishes such as the Atlantic silverside and sand lance, as well as by larger, swifter ones such as scup, Atlantic mackerel and striped searobin. By late spring, however, the number of amphipods had been reduced to a negligible level, and the small fish species became the principal prey for the increasing numbers of larger predatory fish such as striped bass, bluefish and weakfish.

The degree of similarity in the distribution of the individuals of the species present in a fish community is a measure of the evenness or equitability of the species in that community. A community exhibiting a high degree of such evenness would have a similar number of individuals for all or most of the species present, whereas one exhibiting low evenness would have a few abundant species and many scarce or rare species. Because there were no numerical population estimates for the fishes in Fort Pond Bay, no calculations of evenness could be made. However, the

number of species recorded each season according to their relative abundance (Figure 2) affords a means of assessing the evenness that existed. On this basis, the fish community exhibited greater species evenness during the spring than it did during the summer and fall when the number of less abundant species was greater.

The diversity of the fish fauna at Fort Pond Bay is suggested by the 102 species encountered during the present study as well as by the numbers recorded during other studies in nearby waters (Table 2). To the authors' knowledge, the only other accounts of fishes captured by pound net in Long Island waters were those of Murphy and Harper (1915) and an un-

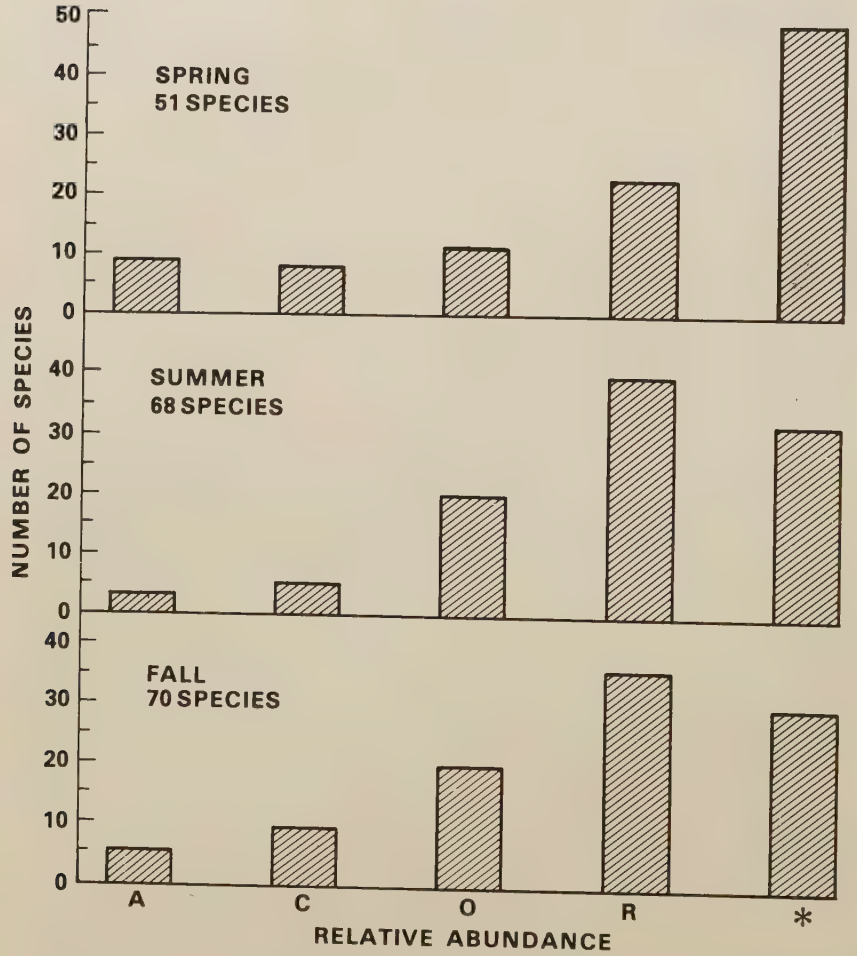

Figure 2. Number of species in different categories of relative abundance at Fort Pond Bay during spring, summer and fall from June 1970 to December 1975. Symbols as follows: A—abundant; C—common; O—occasional; R—rare; *—absent.

TABLE 2. COMPARATIVE NUMBERS OF FISH SPECIES RECORDED IN FORT POND BAY DURING THE PRESENT STUDY AND REPORTED BY OTHER INVESTIGATORS IN NEARBY WATERS

Location	Number of species	Type of gear	Reference
Fort Pond Bay	102	Pound net and others	Present study
Block Island Sound	57	Seine, trawl	New England Power Company (1976)
Narragansett Bay	99	Trawl	Oviatt and Nixon (1973)
Narragansett Bay-Rhode Island Sound	80	Trawl	Jeffries and Johnson (1974)
Long Island Sound			
Millstone, Connecticut	88	Seine, trawl, gillnet	Battelle Columbus Laboratories (1977, 1978)
Milford, Connecticut	37	Trawl	Richards (1963)
Entire Connecticut shore	100	(not specified)	Thomson et al. (1971)
Orient, New York	73	Pound net	Latham*
Shoreham, New York	57	Seine, trawl, gillnet	Austin and Amish (1974)
Shoreham, New York	40	Seine	Zawacki and Briggs (1976)
Jamesport, New York	47	Seine, trawl, gillnet	Long Island Lighting Company (1974)
Atlantic Ocean			
Long Island	71	Seine	Schaefer (1967)
Long Island	75	Seine	Young§

*Unpublished list for years 1910-1963, furnished by Roy Latham to Irwin Alperin of the State Conservation Department in 1964.

§Byron H. Young of the State Department of Environmental Conservation; unpublished data for years 1973-1975 from observations of commercial haul seine catches.

published list furnished by Roy Latham to Irwin Alperin of the State Conservation Department in 1964 which was a checklist for the years 1910-1963 and primarily for the Orient-North Fork area of eastern Long Island. Of the species he listed, 31 were taken during the present study. However, the striped bass, bluefish, butterfish and little skate were absent from his list. Differences in the results of the various studies may be due to the years and areas in which the sampling was done, types of gear used, frequency of sampling and duration of the work. At Millstone, Connecticut, for example, 88 species were taken by seine, trawl and gillnet (Table 2), while Battelle Columbus Laboratories (1977) reported that at least 103 species were taken by those types of gear plus ichthyoplankton tows and impingement on the travelling screens at the Millstone Nuclear Power Station. For the most part, the species which were most abundant during the present study were also common during the other studies.

As has been noted, naturally occurring environmental variations were responsible for the presence of large numbers of fishes of southern origins during the warm summer of 1973. Also taken in Fort Pond Bay during that summer were two species previously unrecorded from New York waters, the glasseye snapper (*Priacanthus cruentatus*) and horse-eye jack (*Caranx latus*) as reported by Hickey et al. (1975). It is the species which occur rarely, or those which occur occasionally but regularly, that may be useful indicators of environmental change. Only when conditions are right will the rare or occasional vistitants be present and, when environmental changes occur, it is these less tolerant species that disappear first. Conversely, a sustained increase or presence of occasional or rare species may be an indicator of environmental change. The more adapatable species at Fort Pond Bay probably are those which are well within their geographical ranges and physiological tolerance limits. It is probable that such species would become scarce only as a result of excessive fishing pressure (probably on a regional basis), large year-class variations or extreme environmental change (natural or man-induced). Under such conditions, species that become relatively less abundant might be replaced by increasing numbers of more tolerant species.

The national estuary study (U.S. Department of the Interior, 1970) rated the estuarine and coastal waters of the United States in three categories, i.e., severely modified, moderately modified and relatively unmodified. All three were found to apply to Long Island's coastline. The waters of the lower Hudson River and New York Harbor, East River, Harlem River and Jamaica Bay were rated as severely modified. Rated as moderately modified were the south shore from Rockaway eastward to Amagansett, the entire north shore and Long Island Sound, the Peconic Bays system and the northwestern part of Gardiner's Bay between Hog Creek Point and Plum Island. The only area rated as relatively unmodified was that of the Atlantic Ocean from Amagansett eastward around Mon-

tauk Point and into Gardiner's Bay, including Gardiner's Island. In this area are the waters of southwestern Block Island Sound and Fort Pond Bay.

Over the years, Fort Pond Bay and vicinity have been the site of a variety of small settlements, commercial enterprises and governmental facilities, as well as the potential site for others. Few recreational fishermen use the bay, but some fish the outer extremes by boat in pursuit of striped bass or bluefish. Lobsters are sometimes taken by pot fishermen in the deeper waters. Nevertheless, it is still relatively unmodified. Continuation of this condition will depend on the degree to which the encroachment of industrial and other activities that affect the environment adversely can be prevented. A diverse fish fauna is one biological indicator of the condition of the aquatic system. The data presented here should serve as a yardstick against which to measure future conditions.

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GENERAL NOTES

OCCURRENCE OF THE GIZZARD SHAD IN THE LOWER MOHAWK VALLEY[1]

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In June 1976, two gizzard shad (*Dorosoma cepedianum*) were taken in Collins Lake, a tributary of the Mohawk River in Schenectady County (N.Y.). They were the first reported specimens for the lower Mohawk Valley. From October 1976 to July 1979, a total of 23 others were collected in this lake.

Collins Lake has an area of 22 hectares and a maximum depth of 9 meters. It is fed by springs which have an annual temperature range of 7° to 10° C. It drains into the Mohawk River through a perennial stream slightly more than 1 kilometer long.

The first records of the gizzard shad for the Mohawk watershed were two specimens taken on November 8, 1973, one at Little Falls and the other 3.2 kilometers west of Frankfort (John J. Hasse, State Department of Environmental Conservation, personal communication). Both of these sites are in the upper reaches of the river 60 and 80 miles, respectively, west of Collins Lake.

In the lower Mohawk Valley, following the collections in Collins Lake in June 1976, gizzard shad were taken in early August 1976 in two small ponds on the south side of the Mohawk River near Niska Isle in Schenectady County (Norman McBride, State Department of Environmental Conservation, personal communication). The adjacent river was sampled in June 1979 (N. McBride, 1980) and the author sampled the two ponds again in July 1981, but no specimens were taken. However, 14 gizzard shad were taken during June-July in 1980 between Lock 7 and Lock 8 (of the Barge Canal), 18 were collected from Collins Lake in late September 1980 and one was reported from the Locks 7-8 sector in June 1981 McBride (1981 and personal communication).

The first gizzard shad reported from the Hudson-Mohawk system north of New York Harbor were 674 specimens taken in the lower Hudson River (less than 70 miles above its mouth) from the intake screens or in the discharge waters of four power plants between October 1972 and February 1973 (Dew, 1973). Two additional specimens were taken at the Albany steam plant at river mile 158 in March 1974 (Cheryl Blum, Niagara Mohawk Power Corp., personal communication). Ichthyological monitoring in the lower river produced further records during the period of November to February in 1977-78, 1978-79 and 1979-80 (Lawler, 1979, 1980a, 1980b).

The specimens from Collins Lake represented two size groups, one ranging from 159 to 168 millimeters in total length and weighing from 44 to 55 grams, while the other ranged from 320 to 357 millimeters in total length and from 297 to 488 grams in weight. These fish were from 2 to 7 years old, with 2 to 4 year olds predominating. The others from the Mohawk River were similar. On the other hand, those from the Hudson River were very largely age 0+ and I+ fish.

Review of the published literature (DeKay, 1842; Kirtland, 1850; Wright, 1918; Breder and Nigrelli, 1934; Greeley, 1935, 1937; Breder, 1938; Miller, 1956, 1960; Bedola, 1966; Dew, 1973; Clady, 1976) and various in-house reports of the State Department of Environmental Conservation (McBride, 1980, 1981; Hasse, 1981) indicates that the gizzard shad is native along the Atlantic coast from New York south and in the Mississippi drainage from where it at some time entered Lake Erie. The accounts also indicate that more recently it reached the Mohawk River, probably via the Barge Canal, and has progressed eastward downstream and into the Hudson River. The incidence of larger, mature fish in the Mohawk Valley and the absence of reports for such specimens in the tidal reaches of the Hudson River, despite the diverse sampling techniques used, further suggest that the younger fish found in the Hudson River are derived from the Mohawk Valley.

[1]Support of the Clean Lakes Program of the Environmental Protection Agency in connection with studies of Collins Lake is gratefully acknowledged. The author appreciates the assistance of the following specialists who have shared their data on gizzard shad: Clifford Creech, Russell Fieldhouse, Dr. John Forney, Dr. Susan O'Connor, Paul Muessig, Martin Daley, Cheryl Blum, Norman McBride, John Hasse, Edward Radle and Dr. C.L. Smith.

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MOVEMENT OF A MALE FISHER IN SOUTHERN NEW YORK

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Movement of fisher (*Martes pennanti*) has been studied by tagging, marking and radio telemetry in various states and provinces throughout its range in North America. DeVos (1952) in Ontario stated that foraging movements of fisher take the form of circuits which are covered in from 3 to 15 days and which may vary from 8 to 20 miles in diameter and 40 to 100 miles in length. Weckwerth and Wright (1968) reported movements of up to 64 miles by an adult male fisher in a fisher transplanting project in Montana. Olsen (1966) reported

recoveries of transplanted fisher in Wisconsin as far as 50 to 60 miles from the release sites. In Ontario, Howard Smith (Ontario Ministry of Natural Resources, personal communication) reported that transplanted fisher had not moved more than 25 miles from the release sites on the Bruce Peninsula and Manitoulin Island. The present note describes the movement of an adult male fisher in southern New York.

In 1976 the State Department of Environmental Conservation undertook to transfer fisher, the majority of which were live trapped in northern New York by cooperating trappers, to the Catskill region in the southern part of the State. As part of this program, a 14-pound male, that had been wild trapped in northern Vermont and donated by the University of Vermont, was ear tagged (#34-35) and released on May 7, 1977 in the Town of Wawarsing in Ulster County. On March 3, 1978 this fisher was tranquilized and recaptured by New Jersey wildlife personnel at Hampton (N.J.) some 85 miles from the release site. The animal was then returned to New York and released again at the original site in the Catskills on March 4, 1978. On April 17, 1979 it was shot near Tripoli in southeastern Pennsylvania (Warren Q. Stump, Pennsylvania Game Commission, personal communication) when it became involved in a fight with several dogs. The distance in a straight line from the release site was 102 miles.

The animal was necropsied by the Department's Wildlife Pathology Unit at Delmar. It weighed 14.58 pounds and had a thick layer of subcutaneous fat as well as heavy mesenteric perirenal fat deposits. There was no gross pathology other than the head wound that caused its death and an older wound from an air rifle pellet in subcutaneous tissue on the left side. This male was determined by the cementum-annuli technique to have been 6 years old at the time of death.

Since this fisher had been held in captivity at the University of Vermont for a period of time, its movements may not be typical of trapped and transferred fishers. Of four others that were transferred directly from the wild, two males were recovered 2.5 and 17.5 miles, and two females 22.8 and 23.5 miles, from the sites where they had been released.

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FOOD OF RECENTLY STOCKED SUBYEARLING CHINOOK SALMON IN LAKE ONTARIO[1]

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Chinook salmon (*Oncorhynchus tshawytscha*), stocked as subyearlings in New York tributaries of Lake Ontario, grow rapidly after migrating to the lake where alewives (*Alosa pseudoharengus*) and rainbow smelt (*Osmerus mordax*) constitute their major food as overyearlings (Gerard LeTendre, N.Y.S. Department of Environmental Conservation, personal communication). Although the summer food of naturally reproduced subyearlings in a tributary stream was reported by Johnson (1981b), information on the food of juveniles once they enter the lake has been lacking. Data are reported here for hatchery fish that had been stocked within a week of the time they were collected.

[1]The author wishes to thank Emily Z. Johnson of the University of New York College of Environmental Science and Forestry at Syracuse for assistance in the field, and Leslie Wedge and Gerard LeTendre of the New York State Department of Environmental Conservation for reviewing the manuscript.

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The specimens examined were collected in Lake Ontario at Brennan's Beach about 1 kilometer north of the Salmon River estuary in Oswego County, New York. The sample consisted of 26 fish taken on June 14, 1980 and 49 fish taken on May 22, 1981. The two groups averaged about 82 millimeters and 72 millimeters in total length, respectively, and were taken at water depths of up to 1.3 meters with a 12-meter bag seine that was drawn perpendicular to the shore. The sampling site had a uniformly sand bottom. During the late spring and early summer in 1977 and 1978, naturally reproduced age 0 chinook smolts had been collected in this same area (Johnson and Ringler, 1981).

The stomach contents of the fish collected were examined on a dry weight basis as described by Johnson (1981a) and are summarized in Table 1. All the specimens examined contained food, with the principal prey being fish eggs, adult chironomids and terrestrial coleopterans in 1980, and adult chironomids and homopterans in 1981. Although, due to digestion, the fish eggs could not be identified, the salmon collected in 1980 were associated with large numbers of emerald shiners (*Notropis atherinoides*) from which ripe eggs and milt were

Table 1. Stomach Contents, According to Percentage of Dry Weight, For Recently Stocked Subyearling Chinook Salmon in Lake Ontario

Taxon	1980	1981
Aquatic organisms		
Amphipoda	1.6	0.6
Zygoptera (nymph)	. .	1.3
Trichoptera (pupa)	1.5	0.5
Elmidae (larva)	0.8	. .
Chironomidae (larva)	1.4	0.8
Chironomidae (adult)	23.7	63.3
Fish eggs	46.3	. .
Sub-total	75.3	66.5
Terrestrial organisms		
Arachnida	0.8	0.8
Diptera (adult)	2.6	4.6
Coleoptera (adult)	10.2	3.2
Hemiptera	. .	1.0
Homoptera	1.7	16.0
Hymenoptera	1.9	3.1
Sub-total	17.2	28.7
Other		
Animal matter (unidentified)	7.5	4.8
Total	100.0	100.0

easily extruded. Fish eggs were absent from the diet in 1981 probably because the salmon were stocked 3 weeks earlier than in 1980 and minnows were not yet spawning in the nearshore area of the lake.

The subyearling salmon probably remain in the nearshore area until early to mid-July when the water temperatures become too warm. This would give them the opportunity to feed on alewife eggs that are usually present commencing in late June.

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INTESTINAL OBSTRUCTION IN RACCOONS CAUSED BY THE ASCARID *BAYLISASCARIS PROCYONIS*

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Heavy infestations of adult ascarids (*Toxocara* sp.) in puppies of the domestic dog (*Canis familiaris*) can cause enteritis, vomiting, periods of diarrhea and constipation, and even blockage of the small intestine (Levine, 1968). In humans there have been cases where from less than 100 to more than 5,000 *Ascaris lumbricoides* have occluded the small intestine. In people, blockages frequently occur when the worms have been irritated by a food or drug ingested by the host (Chandler and Read, 1962). However, although the raccoon (*Procyon lotor*) is the definitive host for the ascarid *Baylisascaris procyonis*, there do not seem to be any reports of this intestinal parasite being pathogenic to the raccoon (Schaffer et al., 1981). This note reports on two cases where *B. procyonis* was the cause of sickness and death in raccoons.

Case 1

On August 30, 1981 a small, lethargic raccoon was seen during daylight hours near a home in the Town of Guilderland in Albany County, New York. The animal was observed to hunch its back periodically and appear to gasp. What was believed to be the same raccoon was found dead the same day and submitted to the Wildlife Pathology Unit for necropsy.

At postmortem it was found to be a juvenile male and very much emaciated (gross weight: 1,192 grams). The deciduous canine teeth were still present, and the gums and tongue appeared pale. The fur of the tail and body was disheveled and matted with burdocks (*Arctium lappa*). The skeletal musculature was pale and the muscles of the limbs appeared atrophic. No evidence of trauma was found. The spleen, liver and mesenteric lymph nodes appeared moderately enlarged, and the adrenal glands were greatly enlarged. Nematodes identified as *Baylisascaris procyonis* (Sprent, 1968) were discovered in the stomach and throughout the small intestine. The presence of the worms in the stomach may have resulted from postmortem migration. A large knot of these worms blocked the hemorrhagic and greatly distended section of the distal ileum. Other than the worms, the alimentary canal contained only a small amount of black liquid feces in the colon.

Microscopic examination of the feces revealed numerous eggs of *B. procyonis* and a few *Strongiyoides* sp. larvae. A culture of the fecal material done by the State Department of Health was negative for *Salmonella* sp. and *Yersinia enterocolitica*. Hematoxylin- and eosin-stained sections of lung and small intestine were not suggestive of canine distemper.

A total of 636 individual ascarids weighing 52 grams (about 4.4 per cent of the gross body weight) were removed from the raccoon's alimentary canal. Many of the adult worms appeared stunted (the average length of 10 adult females was 76 millimeters). Perhaps this was due to the crowding of the ascarids and/or the poor nutritional status of the raccoon. The latter could largely have been caused by the heavy worm infestation.

Case 2

On November 8, 1981 a sluggish raccoon was found on a road in the Town of Palatine in Montgomery County, New York. A man took the sick animal home where it died a few hours later. It was subsequently submitted to the Wildlife Pathology Unit for examination.

At necropsy the raccoon was identified as a juvenile female with abundant supplies of subcutaneous, abdominal cavity and perirenal fat. The animal had a gross weight of 4,217 grams. No traumatic injury was found. The liver and spleen were enlarged, and the mesenteric lymph nodes were greatly enlarged. The mid-portion of the small intestine was very inflamed, enlarged and blocked by a tangle of *B. procyonis*. There were no other outstanding gross pathological findings.

Microscopic examination of scrapings of bladder epithelial cells, stained with Shorr's stain, were negative for the inclusion bodies associated with canine distemper. Examination of the brain for rabies and a culture of the feces for *Y. enterocolitica* and *Salmonella* sp., both done by the State Department of Health, were negative. A total of 141 *B. procyonis* weighing about 41 grams (about 1 per cent of the host's gross weight) were removed from the small intestine; most were in the obstructive mass.

Discussion

Complete blockage of the small intestine in domestic animals usually causes death in a matter of hours to several days unless the condition is alleviated by surgery (Smith and Jones,

1966). It appears likely that the young raccoon in Case 1 was chronically debilitated by the heavy worm infestation and that both animals died from the effects of the ascarid intestinal obstructions.

Heavy infestations of *B. procyonis*, as in the raccoons described here, should be of interest to those concerned with the mortality of rodents and lagomorphs. The eggs of *B. procyonis* pass in the feces of the raccoon and contaminate the environment. When the embryonated eggs are ingested by suitable intermediate hosts such as house mice (*Mus musculus*), white-footed mice (*Peromyscus leucopus*), woodchucks (*Marmota monax*) and cottontail rabbits (*Sylvilagus floridanus*), the hatched larvae may migrate to the brain and spinal chord causing neurological disturbance and death (Tiner, 1953; Nettles et al., 1975; Jacobson et al., 1976). The abnormal behavior of woodchucks, believed caused by *B. procyonis*, has been reported in New York (Fleming and Caslick, 1978). In addition, an epizootic of cerebrospinal nematodiasis, produced by these larvae, occurred in cottontail rabbits and woodchucks in Virginia (Jacobson et al., 1976).

Research is needed into the pathogenicity of this ascarid for the raccoon. However, there probably is an even greater need to investigate the extent of rodent and lagomorph morbidity and mortality caused by *B. procyonis* larvae in areas of high raccoon density.

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FATE OF DEER IN A NO-HUNTING ZONE

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In 1960, pursuant to the provisions of the Fish and Wildlife Management Act, deer hunting was prohibited within a strip averaging about 1/4 mile wide along the north, west and south shores of Big Moose Lake in Herkimer County, New York.[1] A primary reason was the sentiment among cottage owners in this area for protecting the "tame" deer with which they shared their summers (Bowes, 1961).

[1]This restriction was incorporated in the Fish and Game Law in 1970.

To obtain information on the fate of the protected deer, Department personnel live trapped deer in this no-hunting zone during December in 1967. Of the 21 deer captured, 19 were tagged and released. One fawn was already too weak to survive the stress of being trapped, and one adult buck that still had antlers on December 27 was released without an attempt to tag it. The tagged deer included four male and six female fawns, plus one adult buck that had shed its antlers and eight does.

By December 1969, two of the males and one female that had been tagged as fawns, together with one buck and one doe tagged as adults, had been taken by hunters who returned the tags. All five had moved out of the no-hunting zone, the female fawn having been legally shot 7 miles north near the Stillwater Reservoir in the fall of 1968. Two of the does tagged as adults were later found dead in the no-hunting zone, one in February 1971 and the other in the spring of 1980, having survived 4 and 13 years, respectively. Both were possible victims of malnutrition.

The number of tagged deer recovered was too small for statistical analysis. However, it is interesting that all of the fawns, but only half the adults, left the area. It seems reasonable to assume that dispersal was similar among the unrecovered deer also, as well as among those that were on the area but not trapped. If this is representative of the behavior of deer on this area each year, then the prohibition of deer hunting serves to maintain a population of mostly older does that is augmented during the summer by the fawn crop. The adults that remain in the no-hunting zone may eventually die of malnutrition during the winter, and some of those that disperse may return and suffer the same fate.

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A LONG-LIVED WHITE-TAILED DEER

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On May 5, 1980 Claude Bowes of Big Moose, New York, found the remains of a female white-tailed deer that had been trapped and ear tagged near his residence on Big Moose Lake on December 22, 1967 when it was at least 1 1/2 years old. Therefore, during the winter of 1979-80 it would have been at least 14 1/2 years old. It appeared most likely that the deer had died of malnutrition. Nevertheless, it lived to a noteworthy old age, although it did not set a longevity record.

Ozoga (1969), in Michigan, reported recapturing a releasing two female white-tailed deer more than 14 years after they had been trapped and tagged as fawns. Rue (1979: 106-109) reported several captive females that lived more than 16 1/2 years and a "semi-tame" doe in Maine that was killed by a rutting buck at the age of 18 1/2 years. However, Gordon et al. (1975) noted what might constitute an all-time record. This was a female shot on an estate in Orange County, New York, because she had severe hair loss on her face, neck and ears. She was determined, from Giemsa-stained tooth sections, to have been between 19 and 23 years of age and was carrying an 80-day-old fetus.

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